Intelligent
Transportation
Systems (ITS)

U.S. Department
of Transportation

Federal Highway
Administration

# Review of
# ITS Benefits:
# Emerging Successes

DOT/FHWA
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Intelligent
Transportation
Systems (ITS)

# Review of **ITS Benefits:** Emerging Successes

Prepared under contract by Mitretek Systems
Sponsored by the Federal Highway Administration

September 1996
Washington, DC

# EXECUTIVE SUMMARY

The Federal Intelligent Transportation Systems (ITS) program, formerly known as the Intelligent Vehicle Highway Systems (IVHS) program, came into being as a result of the Intermodal Surface Transportation Efficiency Act of 1991. In the years since, the ITS field has developed from a collection of ideas and isolated applications of technology into an interrelated program with initial projects already yielding benefits for the nation's surface transportation system. Since December of 1994, the United States Department of Transportation's (USDOT's) ITS Joint Program Office (JPO) has been actively collecting information on the impact of ITS projects on the operation of the surface transportation network.

This paper continues the process of documenting and publicizing experience with, and prediction of, benefits from ITS in the context of continuing assessment of the ITS program. This empirical benefits review effort is part of a larger effort sponsored by the ITS Joint Program Office to develop benefits knowledge about ITS implementation. This document summarizes major ITS benefits findings while referring the interested researcher to detailed studies or contacts. The progression of papers on the topic of ITS benefits seeks to improve the completeness and reliability of relevant data, with the ultimate goal being validated results from field measurement for all areas of ITS.

The data collection for ITS benefits assessment began by focusing on experience with the federally-funded Field Operational Tests and other deployed systems providing service similar to ITS user services. New sources of data are developing as a result of recent Federal initiatives. In January 1996, the Secretary of Transportation announced "Operation Timesaver", which seeks to install an Intelligent Transportation Infrastructure (ITI) in major US metropolitan areas. In Fall 1996, the ITS Joint Program Office initiated model deployments of the Intelligent Transportation Infrastructure in the New York/New Jersey, Phoenix, San Antonio, and Seattle metropolitan areas. In this same time frame, model deployments of the Commercial Vehicle Information Systems and Networks (CVISN) are also being initiated. Maryland and Virginia are currently developing a prototype version of CVISN and the following states have been announced as deployers of pilot versions of CVISN: California, Colorado, Connecticut, Kentucky, Michigan, Minnesota, and Washington/Oregon. Comprehensive evaluations are a major part of both of these initiatives.

Data in this paper are organized by class and by groups of systems. This document adopts the groups found in the 1996 edition of ***Intelligent Transportation Systems (ITS) Projects:*** Advanced Traveler Information Systems, Advanced Traffic Management Systems, Advanced Public Transportation Systems, Advanced Rural Transportation Systems, Commercial Vehicle Operations, Advanced Vehicle Control and Safety Systems, and Integrated Systems. Benefits data are available from a number of sources that vary in precision, accuracy, and repeatability. Benefits data described in this paper are categorized into the following classes:

Measured - outcome results from field measurement of desired quantities through engineering studies, which are the most compelling

Anecdotal - output measures or estimates made by people directly involved in fielded projects, which are also compelling, but less reliable than measured outcomes in terms of quantitative benefits estimates

Predicted - results from analysis and simulation, which can be useful tools to estimate impact of an ITS deployment when field experience is not available or when projects are not of sufficient scope to determine system impact

The terms “outcome measure” and “output measure” are adopted from the Government Performance and Results Act of 1993.

The evaluation of ITS and precursor systems has been an ongoing process. Significant knowledge is available, but significant gaps in knowledge also exist. Table ES-l summarizes the availability of benefits data.

**Types of ITS**

| | **Travel Management** | | | | | | |
|---|---|---|---|---|---|---|---|
| **Measure** | **ATIS** | **ATMS** | **APTS** | **ARTS** | **C V O** | **AVCSS** | **Integrated** |
| **Time** | Measured Anecdotal Predicted | Measured Anecdotal Predicted | Measured Anecdotal | | Measured | Predicted | |
| **Crashes** | Anecdotal Predicted | Measured Anecdotal | | Measured Anecdotal Predicted | Anecdotal Predicted | Measured Anecdotal Predicted | |
| **Fatalities** | Anecdotal | | | Predicted | Predicted | | Anecdotal Predicted |
| **Throughput** | Predicted | Measured | | | | Predicted | |
| **Cost** | | Measured | Measured Predicted | | Measured Anecdotal Predicted | | Predicted |
| **Customer Satisfaction** | Measured Anecdotal | Measured | Anecdotal | | Measured Predicted | | |

Table ES-l - Summary of ITS Benefits Data Availability

Reduction in ***travel time*** and ***delay*** is a major goal of most ITS components. The ITI initiative of the US DOT acquired the theme “Operation TimeSaver". Figure ES- 1 shows the range of percentage reductions in travel times achieved in some operational systems. The reader should refer to reference documents to interpret the conditions under which these ranges are reported. Figure ES-l and subsequent figures illustrate the range of benefits reported from either measured data alone, or all classes of benefits data, as indicated in the caption. The number of sources used to estimate the range of benefits is shown under the axis label indicating the type of system considered. Some of the sources provide a single number while others provide a range of numbers.

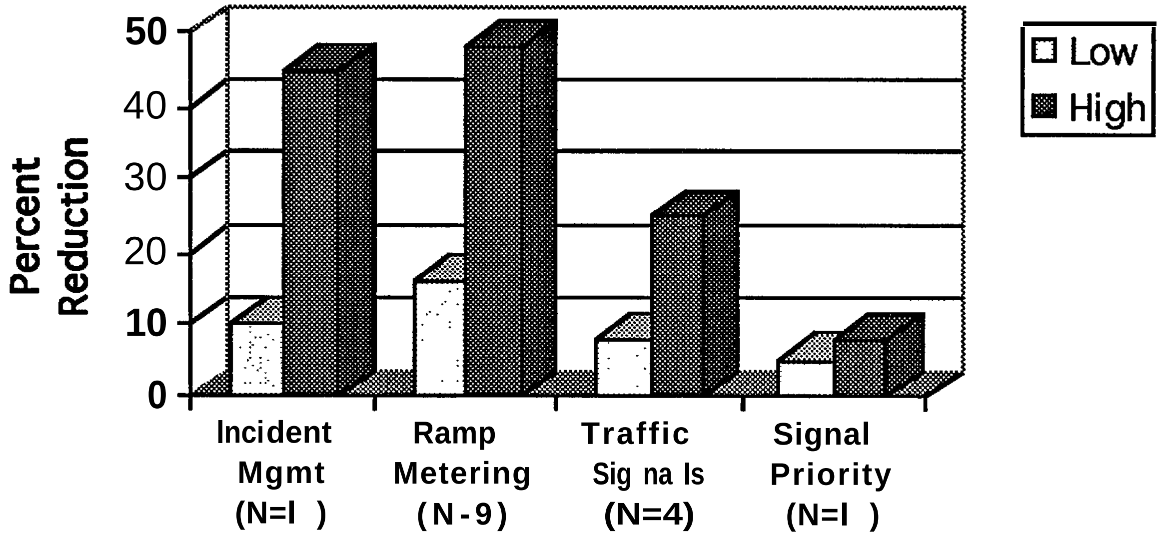


Figure ES-l - Range of Measured Travel Time Reduction Benefits

Reducing the number of ***crashes*** is an important aspect of improving safety. While the relationships between reduced crashes and other important statistics such as fatalities, injuries, and nonrecurrent delay vary with a number of factors, reducing crashes will tend to improve all of these statistics. Figure ES-2 shows the percentage reduction in crashes achieved in some operational systems. (Note: MCSAP refers to the Motor Carrier Safety Assistance Program.)

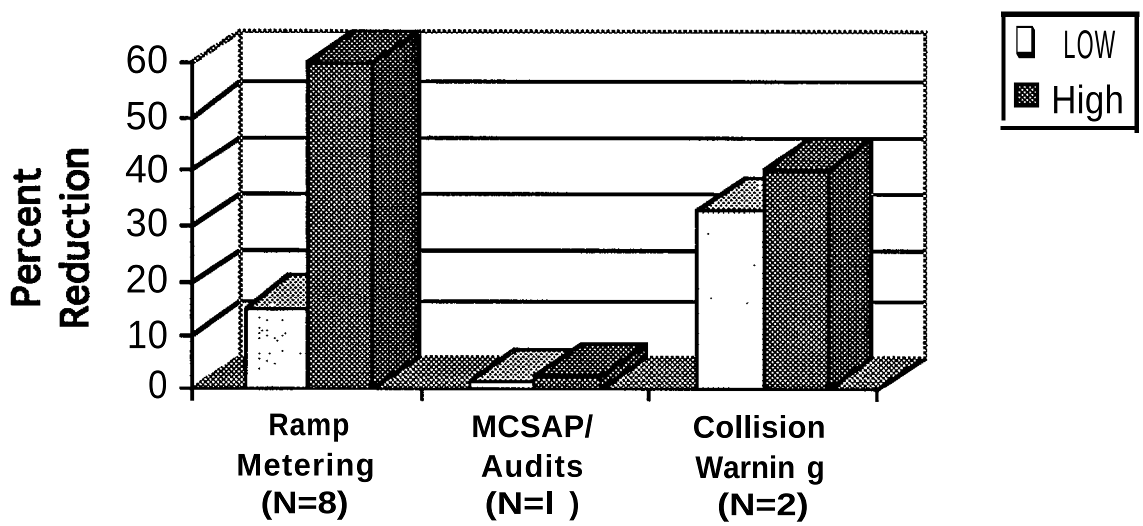


Figure ES-2 - Range of Measured Crash Reduction Benefits

Since a ***fatality*** resulting from a crash can be prevented if the crash is avoided, systems that reduce the number of crashes also reduce fatalities. In addition, systems that reduce the severity of the crash, the consequences of the crash, or emergency medical services response times to victims of the crash also reduce the number of fatalities and the extent of injuries. The ITS benefits data on fatality reduction are mostly predicted versus measured in the field due to the long-term nature of fatality reduction efforts.

Many ITS components seek to optimize use of existing facilities and right-of-ways so that mobility and commerce needs can be met while reducing the need to construct new facilities or expand right-of-ways. One approach is to improve throughput in number of people, number of vehicles, or amount of goods moved per unit of time while maintaining or improving level of service. Although some ITS components address throughput of individual facilities, other components seek to improve network throughput, which is more difficult both to define and to measure. Figure ES-3 shows the percentage increases in maximum throughput achieved in operational systems and increases in throughput expected using collision avoidance systems. (Note: ETC refers to Electronic Toll Collection.)

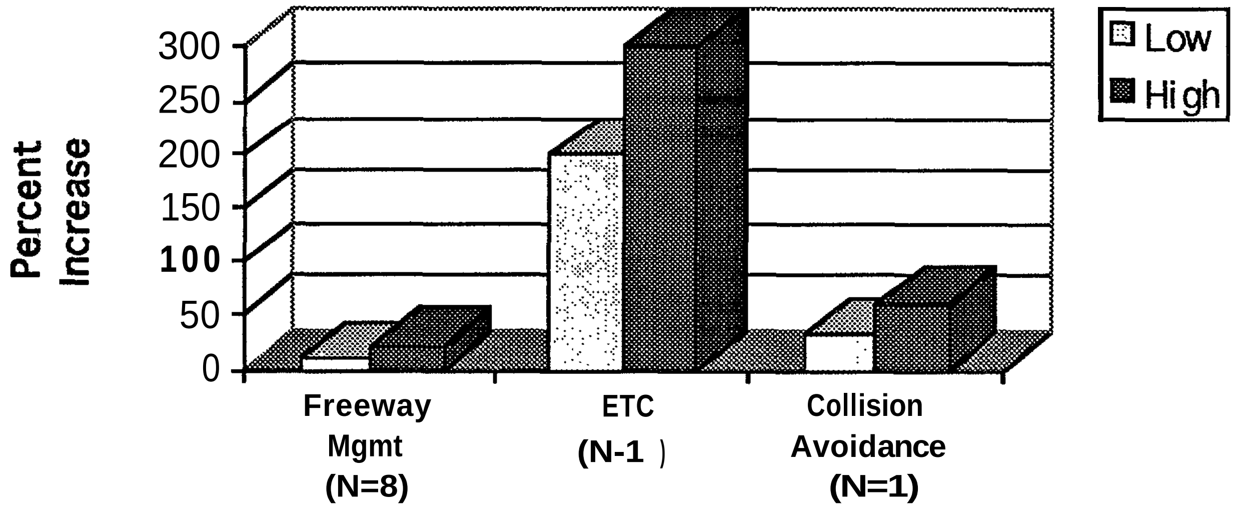


Figure ES-3 - Ranges of Throughput Improvement Benefits

Implementing ITS requires funding. However, frequently ITS implementation reduces operating costs and allows productivity improvements. In addition, ITS options may have lower acquisition costs compared to traditional transportation improvement options, and may have lower life-cycle costs due to operating cost and productivity improvements. Figure ES-4 shows percentage improvement in operating costs and productivity. (Note: AVL refers to Automatic Vehicle Location and CAD refers to Computer-Aided Dispatching.)

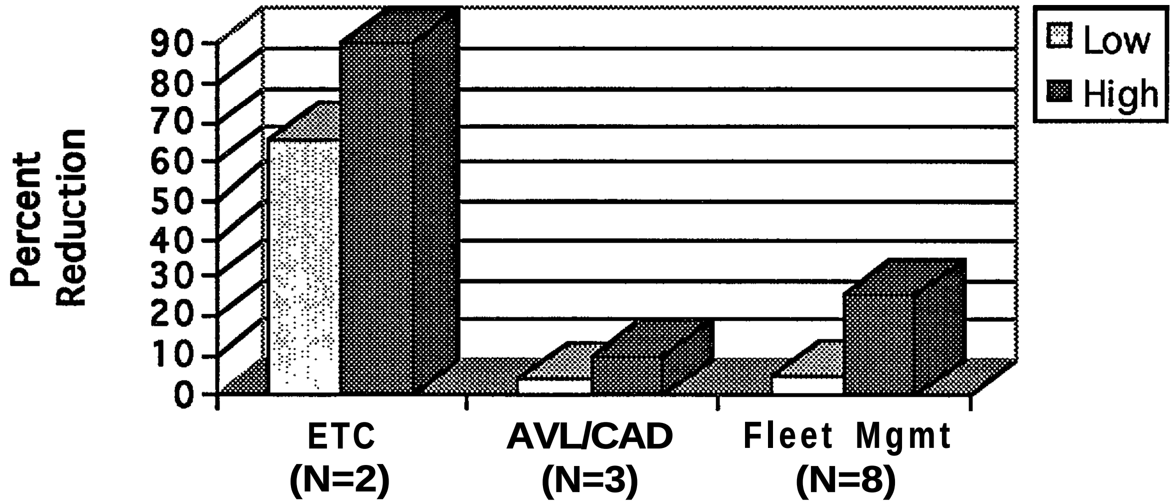


Figure ES-4 - Range of Experienced Improvement in Operating Costs and Productivity

***Customer satisfaction*** indicates the degree to which transportation consumers are accommodated by ITS service offerings. Although satisfaction is difficult to measure directly, measures related to satisfaction can be observed including amount of travel in various modes, mode options, and the quality of service as well as the volume of complaints and/or compliments received by service providers. In general, users of ITS services are highly satisfied with the products.

While the ITS benefit results presented in this paper indicate significant areas of positive impact, there is still much to do to fully demonstrate and assess the potential of ITS. The preceding discussion has summarized some benefits of ITS; however, the conditions under which ITS will yield positive results and the magnitude of the resulting improvements are still not well understood. The existing results vary in magnitude of benefit due to, among other factors, operating conditions, baseline conditions, and maturity of installation. To make further progress, the ITS community needs to gain additional understanding of the results of ITS implementation by filling in missing data and continuing to collect and refine results in areas where data are present, but incomplete. Additionally, data on cost of installation and operation are sparse and need to be examined more fully.

## PREFACE

The Federal Intelligent Transportation Systems (ITS) program, formerly known as the Intelligent Vehicle Highway Systems (IVHS) program, came into being as a result of the Intermodal Surface Transportation Efficiency Act of 1991. In the years since, the ITS field has developed from a collection of ideas and isolated applications of technology into an interrelated program with initial projects already yielding benefits for the nation's surface transportation system. Since December of 1994, the United States Department of Transportation's (USDOT's) ITS Joint Program Office (JPO) has been actively collecting information on the impact of ITS projects on the operation of the surface transportation network.

The first ITS benefits document sponsored by the JPO was published in August 1995. Between the publication of that document and this document, the ITS program has continued to develop. In January 1996, the Secretary of Transportation announced "Operation Timesaver", which seeks to install an Intelligent Transportation Infrastructure (lTI) in major US metropolitan areas. In support of the announcement, a second paper focused on the benefits of ITI implementation.

The present paper builds upon empirical results from field operations of deployed systems, as well as provides new benefits information based upon modeling studies and statistical, meta-evaluation studies. It also takes advantage of results of ITS field operational tests. The final evaluation reports of TravTek and other operational tests are now available and are referenced in this paper.

This paper also differs from preceding papers in that it reflects the increased emphasis that has been placed on the use of evaluation results to satisfy the requirements of the Government Performance and Results Act of 1993. Its organization reflects a focus on the use of a limited number of key measures of ITS effectiveness. The intent is to focus on a few measures that are robust enough to represent the goals and objectives of the entire ITS program, yet are few enough to be affordable in tracking the progress of the ITS program on a yearly basis. These measures are: Time, Crashes, Fatalities, Throughput, Cost, and Customer Satisfaction. Other important measures include Emissions Reduction and Fuel Savings.

This paper is intended to be a reference document. It highlights benefits identified by other authors and refers the reader to information sources. The interested reader is encouraged to obtain source documents to appreciate the assumptions and constraints placed upon interpretation of results.

It is the intent of the ITS Joint Program Office to update this paper periodically. In Fall 1996, the ITS Joint Program Office initiated model deployments of the Intelligent Transportation Infrastructure in the New York/New Jersey, Phoenix, San Antonio, and Seattle metropolitan areas. In this same time frame, model deployments of the Commercial Vehicle Information Systems and Networks (CVISN) are also being initiated. Maryland and Virginia are currently developing a prototype version of CVISN and the following states have been announced as deployers of pilot versions of CVISN: California, Colorado, Connecticut, Kentucky, Michigan, Minnesota, and Washington/Oregon. Comprehensive evaluations are a major part of both of these initiatives.

Over the next 12 to 18 months, baseline data will be collected at model deployment sites. This will be followed by at least 12 months of benefits data collection. Within the next two years, a systematic picture of the benefits of ITI and CVISN model deployments will begin to come together.

In the nearer term, the ITS field operations test program will mature. It is anticipated that the next issue of this paper will focus more on the results from these tests. There are also many ITS efforts initiated by states, local governments, and private enterprise. Readers who are aware of important ITS benefits and cost information from these and other sources are encouraged to send reference documents to:

Director of Program Assessment
ITS Joint Program Office
Federal Highway Administration (HVH-1)
400 7th Street, S.W.
Washington, DC 20590

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# SECTION 1

# INTRODUCTION

## 1.1 GOALS FOR THIS PAPER

This paper continues the process of documenting and publicizing experience with, and prediction of, benefits from Intelligent Transportation Systems in the context of continuing assessment of the ITS program. This empirical benefits review effort is part of a larger effort sponsored by the ITS Joint Program Office to develop benefits knowledge about ITS implementation. A diagram showing the larger benefits assessment effort is shown in Figure 1. This document summarizes major ITS benefits findings while referring the interested researcher to detailed studies or contacts. The progression of papers on the topic of ITS benefits seeks to improve the completeness and reliability of relevant data, with the ultimate goal being validated results from field measurement for all areas of ITS. Benefits data are an important source of information used in simulation and analysis activities as they add realism to the setting of modeling parameters and verify results from statistical analysis work.

## 1.2 PREVIOUS BENEFITS PAPERS

Much of the material presented in this paper has been published in three previous documents. The first, entitled "Assessment of ITS Benefits - Early Results," presented the initial stories related to ITS benefits[1]. The second paper, prepared in conjunction with the announcement of the Intelligent Transportation Infrastructure (ITI) initiative, focused on the benefits of only the ITI elements, with particular emphasis on travel time reductions[2]. The third paper, presented at the ITS America Annual Meeting in April 1996, discussed only benefits observed in the field or projected directly from field experience[3].

## 1.3 DEFINITION OF TERMS

Several initiatives have advanced the definition of the ITS program and the way that ITS benefits are being portrayed. These include a summary of ITS projects[4], the definition of the National ITS Architecture[5], the Commercial Vehicle Information Systems and Network[6], and the Government Performance and Results Act of 1993[7]. This section reviews the definition of terms developed in these initiatives because they are used as the foundation for succeeding discussions of ITS benefits.

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1 "Assessment of ITS Benefits - Early Results," US Department of Transportation, FHWA-JPO-96401, August 1995.

2 "Intelligent Transportation Infrastructure Benefits: Expected and Experienced," US Department of Transportation, FHWA-JPO-96-008, January 1996.

3 "Assessment of ITS Benefits - Results from the Field," ITS America Sixth Annual Meeting, April 1996.

4 "Intelligent Transportation Systems (ITS) Projects," US Department of Transportation, January 1996.

5 "ITS Architecture: Mission Definition," prepared for Federal Highway Administration by the Joint Architecture Team of Loral Federal Systems and Rockwell International, June 1996.

6 "Introduction to Commercial Vehicle Information Systems and Networks," prepared for Federal Highway Administration by the Johns Hopkins University Applied Physics Laboratory, Preliminary, January 1996.

7 Government Performance and Results Act of 1993, Public Law 103-62, 103d Congress, August 3, 1993.

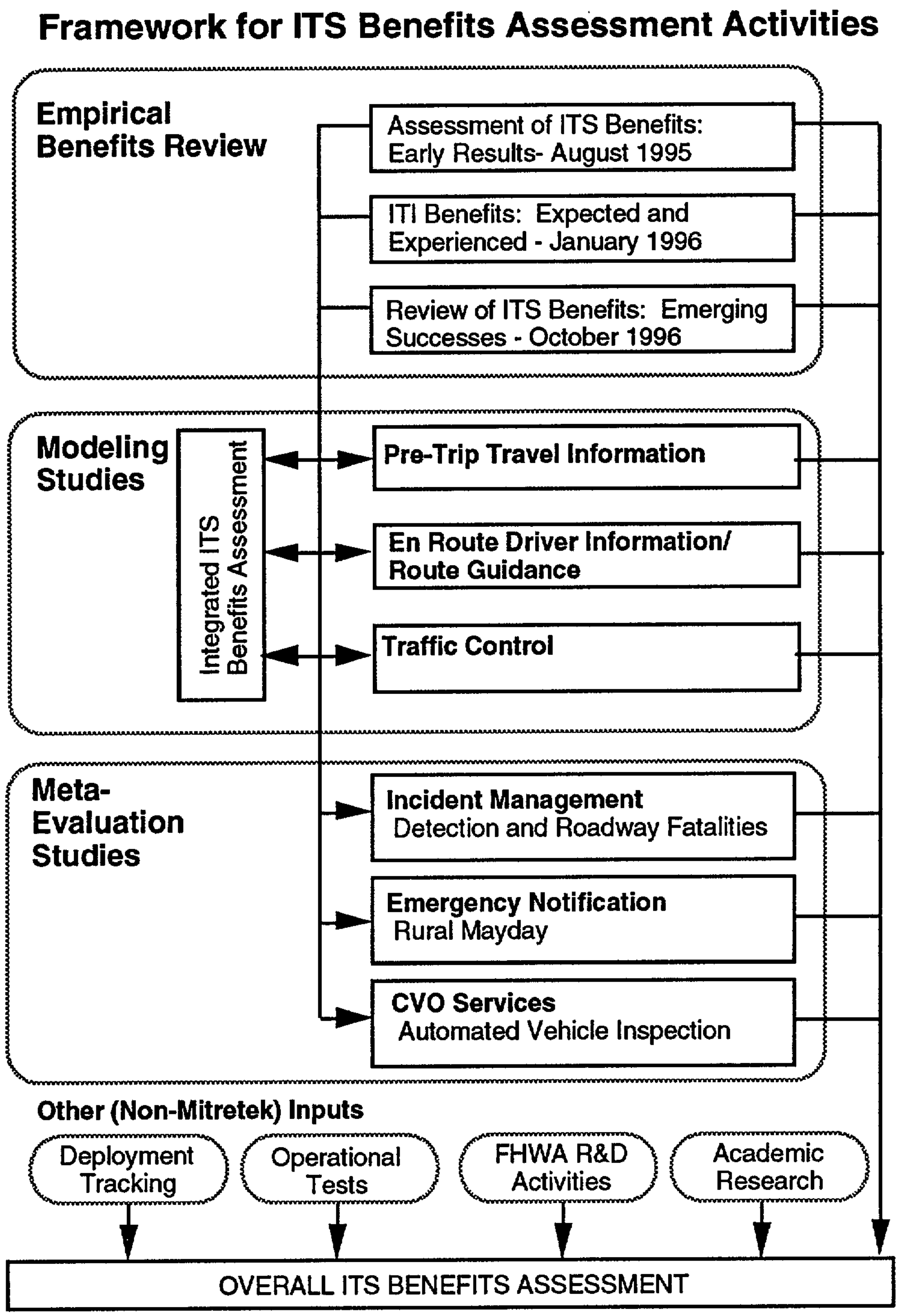


Figure 1 - Some Current Benefits Assessment Activities
(Includes activities primarily performed by Mitretek Systems)

### 1.3.1 Classes of Benefits Data

Benefits data are available from a number of sources that vary in precision, accuracy, and repeatability. Benefits data described in this paper are categorized into the following classes:

Measured - outcome results from field measurement of desired quantities through engineering studies, which are the most compelling

Anecdotal - output measures or estimates made by people directly involved in fielded projects, which are also compelling, but less reliable than measured outcomes in terms of quantitative benefits estimates

Predicted - results from analysis and simulation, which can be useful tools to estimate impact of an ITS deployment when field experience is not available or when projects are not of sufficient scope to determine system impact

The terms “outcome measure” and “output measure” are adopted from the Government Performance and Results Act of 1993. Outcome measures relate directly to the goals of the ITS program, while output measures (which are grouped with experiential estimates as the anecdotal class) identify results which bear some relationship to the goals, but do not directly measure the degree of achievement of those goals. For example, in discussing the achievement of the goal of reducing travel time by use of freeway management systems, outcome measures would be such things as average travel time and average delay found in a before-and-after study. An output measure would be the number of additional lane miles with freeway management systems installed. While the installation or expansion of a freeway management system does not directly define the value of such systems, departments of transportation invest in such procurements because they have reliable indications of their value.

### 1.3.2 System Groups

This document adopts the groups of systems found in the 1996 edition of ***Intelligent Transportation Systems (ITS) Projects.*** Advanced Traffic Management Systems (ATMS) seek to improve efficient management of traffic on freeways and surface streets using traffic monitoring, communications, traffic signal systems, and freeway management systems. Advanced Traveler Information Systems (ATIS) provide information to travelers on both highway and transit system performance before and during travel using infrastructure-provided equipment as well as personal and vehicle-based devices. Advanced Public Transportation Systems (APTS) seek to improve operation and encourage use of shared-ride modes by applying technologies in fleet management, traveler information, and electronic fare payment. Advanced Rural Transportation Systems (ARTS) provide traveler information and public transportation in forms of interest to travelers in rural areas including mayday, hazard warning, crash avoidance, and routing and tourist information for individual travelers and information, scheduling, dispatching and sponsor billing for public transportation providers. The ARTS group is fundamentally different than the other system groups in that most systems in the ARTS group could also be represented in other groups (i.e. ATIS, ATMS, APTS, CVO, and AVCSS). In fact, this benefits report includes multiple entries under ARTS and other groups. Commercial Vehicle Operations (CVO) assist the safe and efficient movement of trucks and buses using electronic screening and identification systems, advances in administrative function automation, automated inspections and reporting, hazardous materials response, and on-board monitoring. Advanced Vehicle Control and Safety Systems (AVCSS) will use technology to improve vehicle control and crash avoidance, with the full implementation to take the form of automated operation on specified facilities. Integrated systems incorporate many of the aspects of ATMS, ATIS, APTS, and possibly ARTS into a single facility or coordinated facilities to take advantage of improvements in coordination, communication, and infrastructure investment.

### 1.3.3 Related Systems Initiatives

Several initiatives are progressing to integrate ITS elements into systems of systems with particular focuses. These initiatives include the National ITS Architecture, Commercial Vehicle Information Systems and Networks (CVISN), and the ITI. The National ITS Architecture is the framework for interconnecting subsystems which together provide the ITS user services through allocated functionality and defined interfaces. This architecture is open and flexible to prevent unnecessary restriction to implementation choice and to accommodate the varied needs of the public and private sectors. At the same time, the architecture definition must be sufficiently precise to ensure a transportation and communication system design that is both compatible and interoperable across the nation. CVISN are the collection of information systems and communications networks that provide support to CVO. CVISN include information systems owned and operated by governments, carriers, and other stakeholders. A prototype of CVISN is underway in Virginia and Maryland, to be followed by pilot deployments in the following states: California, Colorado, Connecticut, Kentucky, Michigan, Minnesota, and Washington/Oregon. The ITI includes core ITS elements that can be implemented in a coordinated fashion to leverage investment in enabling technology. ITI components include traffic signal control, freeway management, highway-rail crossing protection, incident management and emergency management services, traveler information, transit management, electronic fare payment, and electronic toll collection. A Model Deployment Initiative to integrate ITI components is underway in Seattle, Washington, San Antonio, Texas, Phoenix, Arizona, and the New York/New Jersey metropolitan areas.

## 1.4 SCOPE AND ORGANIZATION OF DOCUMENT

Section 2 of this document presents summaries of ITS benefits grouped by key outcome measures identified by the USDOT. Section 2.1 discusses time benefits of ITS. Section 2.2 discusses benefits related to crashes. Section 2.3 presents benefits related to fatalities. Section 2.4 presents improvements in throughput. Section 2.5 discusses cost reductions. Section 2.6 discusses customer satisfaction. Section 2.7 discusses other important outcomes such as emission and fuel impacts. Within the discussion of each measure, benefits are grouped by system type including Advanced Traveler Information, Advanced Traffic Management, Advanced Public Transportation, Advanced Rural Transportation, Commercial Vehicle Operations, Advanced Vehicle Control and Safety, and Integrated. Each system type for which benefits data are available is discussed in terms of mechanisms by which benefits will accrue followed by examples of measured, anecdotal, and predicted benefits. Output measures are grouped with anecdotal experience. In areas where no results are available, corresponding sections are omitted.

Since some systems can provide benefits in multiple related areas (e.g. time and throughput), the same reports are sometimes cited in multiple sections. This duplication is deliberate and allows each benefits subsection to stand alone.

# SECTION 2

# BENEFITS OF ITS

Table 1 summarizes the availability of benefits data for each system type. Presence of benefits in a cell does not mean that complete benefits information is available. The remainder of Section 2 presents summary information about the data regarding each system type on a measure by measure basis for the key measures. The section ends with a general consideration of impacts of ITS on fuel use and emissions. No coverage is given to areas with blank cells.

**Types of ITS**

| | Travel Management | | | | | | |
|---|---|---|---|---|---|---|---|
| **Measure** | **ATIS** | **ATMS** | **APTS** | **ARTS** | **CVO** | **AVCSS** | **Integrated** |
| **Time** | Measured<br>Anecdotal<br>Predicted | Measured<br>Anecdotal<br>Predicted | Measured<br>Anecdotal | | Measured | Predicted | |
| **Crashes** | Anecdotal<br>Predicted | Measured<br>Anecdotal | | Measured<br>Anecdotal<br>Predicted | Anecdotal<br>Predicted | Measured<br>Anecdotal<br>Predicted | |
| **Fatalities** | Anecdotal | | | Predicted | Predicted | | Anecdotal<br>Predicted |
| **Throughput** | Predicted | Measured | | | | Predicted | |
| **Cost** | | Measured | Measured<br>Predicted | | Measured<br>Anecdotal<br>Predicted | | Predicted |
| **Customer Satisfaction** | Measured<br>Anecdotal | Measured | Anecdotal | | Measured<br>Predicted | | |

Table 1 - Summary of ITS Benefits Data Availability

## 2.1 TIME

Reduction in travel time and delay is a major goal of most ITS components. The ITI initiative of the US DOT acquired the theme "Operation TimeSaver". Figure 2 shows the range of percentage reductions in travel times achieved in some operational systems. The reader should refer to reference documents to interpret the conditions under which these ranges are reported. Figure 2 and subsequent figures illustrate the range of benefits reported from either measured data alone, or all classes of benefits data, as indicated in the caption. The number of sources used to estimate the range of benefits is shown under the axis label indicating the type of system considered. Some of the sources provide a single number while others provide a range of numbers.

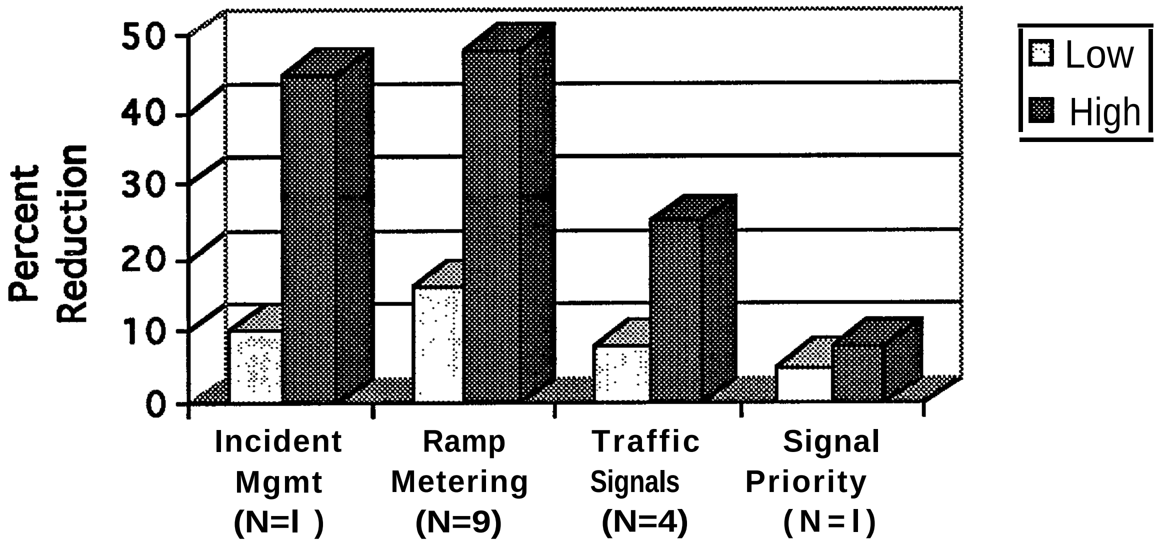


Figure 2 - Range of Measured Travel Time Reduction Benefits

### 2.1.1 Time Benefits of ATIS

Traveler information systems can reduce travel times by giving travelers the information needed to select the most appropriate route, mode, or departure time for a given trip. With this information individual travelers can make selections that reduce their travel time while reducing the total network delay. Traveler information is particularly beneficial in situations when travelers are otherwise unaware of travel conditions either due to incidents on the highway network or forecasted critical weather or for travelers who are unfamiliar with the area.

#### 2.1.1.1 Measured Time Benefits of ATIS

The Information for Motorists (INFORM) program is an integrated corridor management system on Long Island, New York providing information via variable message signs (VMSs) and control using ramp meters serving parallel expressways and some signal coordination on arterials. The program stretches back to concept studies in the early 1970's and a major feasibility study performed from 1975 to 1977. The implementation progressed in phases starting with VMSs, followed by ramp meters in 1986 and 1987 and completed implementation by early 1990. ***Estimates of delay savings due to motorist information*** [8] ***reach as high as 1900 vehicle-hours for a peak period incident and 300,000 vehicle-hours in incident related delay annually.***

In-vehicle navigation devices can benefit users of such devices in terms of travel time and route finding. Field Operational Test experience is producing data that suggest system benefits when wider deployment appears. ***The TravTek test in Orlando found that for unfamiliar drivers, wrong turn probability decreased by about 33% and travel time decreased by 20% relative to***

[8] Smith, S. and Perez, C., "Evaluation of INFORM - Lessons Learned and Application to Other Systems," Conference Paper Presented at 71st TRB, January 1992.

***using paper maps, while travel planning time decreased by*** 80%[9]. The ADVANCE project in the Northwest suburbs of Chicago tested the time effects of dynamic route guidance using a yoked vehicle study on an arterial network with limited probe data. The aggregate data set showed no significant time savings offered by dynamic route guidance; however, there was a small sample size and relatively high standard deviation[10]. It did appear that the dynamic route guidance concept, as implemented in ADVANCE, can detect some larger delays and help drivers avoid them. The Pathfinder project implemented an in-vehicle navigation and motorist information system including access to real-time traffic information. The project was implemented in the Los Angeles area. The evaluation[11] stated that the Pathfinder navigation system delivered meaningful user benefits including fewer travelers failing to follow their desired route. Since in-vehicle systems operate in a complex environment, specific results vary with conditions and options selected.

#### 2.1.1.2 Anecdotal Time Benefits of ATIS

Studies also indicate that travelers are interested in receiving traffic information and are willing to react to avoid congestion and delay. In focus groups for the Atlanta, Georgia, Advanced Traveler Information Kiosk Project[12], 92% - 98% of participants found the current information on accidents, alternate routes, road closures, and traffic congestion to be useful and desirable. ***A survey in Marin County, California, showed that if regular commuters had been presented with alternate routes including travel time estimates, 69% would have diverted and would have saved an average of I7 minutes[13]. A pilot project in the Netherlands found a 40% increase in route diversions based on traffic information provided to the 300 vehicles equipped with FM sideband data receivers[14].***

According to studies related to INFORM, ***drivers will divertfrom 5% to 10% of the time when passive (no recommended action) messages are displayed and twice that when messages include recommendations to divert.*** Convenient alternate routes also have a major impact on diversion. Drivers will start to divert several ramps prior to an incident, with typically 3% to 4% of drivers using an individual exit ramp. ***This represents an increase in ramp usage of 40-70%. Surveys performed in the Seattle, Washington, and the Boston, Massachusetts, areas indicate that 30% - 4O%[15] of travelers frequently adjust travel patterns based on travel information.*** Of those who change travel patterns, about 45% change route of travel and another 45% change time of travel; an additional 5% - 10% change travel mode.

#### 2.1.1.3 Predicted Time Benefits of ATIS

Simulations performed for the Architecture program using an urban scenario also produced encouraging indications of potential ATIS benefits. ***For networks with congestion causing***

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9 Inman, V., et al., "TravTek Evaluation Orlando Test Network Study," FHWA-RD-95-162, Federal Highway Administration, January 1996.

10 Schafer, J. et. al., "Field Test Effectiveness of ADVANCE Dynamic Route Guidance," draft final report, Northwestern University Transportation Center, July 1996.

11 Pathfinder Evaluation Report, Prepared for California Department of Transportation, JHK & Associates, Pasadena, CA, February 1993

12 "Advanced Traveler Information Kiosk Project: Summary Report - Focus Groups," Catherine Ross and Associates, Inc., undated.

13 Khattak, A., Kanafani, A., and Le Colletter, E., "Stated and Reported Route Diversion Behavior: Implications on the Benefits of ATIS", University of California - Berkeley, UCB-ITS-PRR-94-13, 1994.

14 Broeders, W. P. B., "RDS/TMC as Traffic Management Tool and Commercial Product," Proceedings of the Second World Congress on Intelligent Transportation Systems, Yokohama, Japan, November 1995.

15 Air Quality Benefit Study of the SmarTraveler Advanced Traveler Information Service, Tech Environmental, Inc., July 1993.

***increases of up to a factor of 3 from free flow travel time on a network experiencing periodic saturation, drivers with in-vehicle traffic information experience an 8% - 20% advantage in travel time.*** As the network becomes loaded, but before congestion significantly affects travel time, the advantage to drivers with in-vehicle traffic information is smaller. ***For experienced commuters, the simulation predicts an aggregate travel time benefit of*** 7% - ***12%.*** Benefit to longer trips is more significant in both absolute and relative terms than benefit to shorter trips, consistent with a greater opportunity for advantageous diversion. The simulations were performed using an ATIS market penetration level of ***5%. A separate simulation study predicted thatpretrip information on roadway conditions could result in a system-wide delay reduction of 21% when a capacity reducing incident occurs, off-road travel options are present, and pre-trip information is universally available[16].***

### 2.1.2 Time Benefits of ATMS

Traffic management systems reduce travel time by improving the flow of traffic both in incident and nonincident conditions. By using improved communications and control techniques, traffic management can reduce delay in uncongested situations, adjust control devices to improve utilization of available capacity and thereby increase throughput in congested situations, and respond more quickly to incidents to restore full capacity.

#### 2.1.2.1 Measured Time Benefits of ATMS

Incident management programs show concrete promise of reducing the 50 - 60% of delay associated with traffic congestion attributable to incidents. The Institute of Transportation Engineers (ITE) has estimated 10% - 45% decreases in travel time during congested times using incident management programs included in freeway management systems[17]. The Maryland CHART program is in the process of expanding to more automated surveillance with lane sensors and video cameras. The evaluation of the initial operation of the program shows a benefit/cost ratio of 5.6:1, with most of the benefits resulting from a 5% (2 million vehicle-hours per year) decrease in delay associated with non-recurrent congestion[18]. Freeway service patrols, which began prior to the emergence of ITS technologies, but are being incorporated into traffic management centers, significantly reduce the time to clear incidents, especially minor incidents. The Minnesota Highway Helper Program[19] reduces the duration of a stall (the most frequent type of incident representing 84% of service calls) by 8 minutes. ***Based upon representative numbers, annual benefits through reduced delay total $1.4 million for a program that costs $600,000 to operate.***

Freeway management systems and ramp meters show good results in reducing travel times on congested roadway segments. According to a longitudinal study of the ramp metering/freeway management system in the Seattle, Washington area over a six year period[20],freeways ***in the area show a growth in traffic volume of 10% to 100% along various segments of I-5 while speeds have remained steady or increased up to*** 20%. The improvements have occurred while average delays caused by ramp meters have remained at or below 3 minutes. According to the Minnesota DOT Freeway Operations Meeting Minutes, ***average peak period speeds have risen from 34 mph to 46 mph***

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16 Glassco, R., et al, "Studies of Potential Intelligent Transportation Systems Benefits Using Traffic Simulation Modeling," Mitretek Systems, MP96WOOOO101, March 1996.

17 Meyer, M., ed., A Toolbox for Alleviating Traffic Congestion, Institute of Transportation Engineers, Washington, DC, 1989.

18 COMSIS Corporation, "CHART Incident Response Evaluation Final Report," Silver Spring, MD, May 1996.

19 Minnesota Department of Transportation, "Highway Helper Summary Report - Twin Cities Metro Area," Report # TMC 07450-0394, July 1994.

20 Henry, K. and Meyhan, O., "6 Year FLOW Evaluation," Washington State DOT, District 1, January 1989.

***while peak period demand increased by 32%.*** In studies comparing 1987 to 1990 flows in the area of the INFORM system measuring benefits from ramp metering in combination with motorist information, ***freeway speeds increased 13% despite an increase of 5% in VMT for the PM peak***[21]. The relative merits of ramp metering and motorist information can not be discerned from the available data. The number of detectors showing speeds of less than 30 MPH decreased 50% for the AM peak. Average queue lengths at ramp meters ranged from 1.2 to 3.4 vehicles, representing 0.1% of vehicle hours traveled. A survey of traffic management centers using ramp metering[22] reported similar findings of ***speed increases of 16% - 62% and travel time improvements of up to 48% while demand increased 17%*** - 25%. (Information repeated in Section 2.4.2.1)

Traffic signal system improvements are frequently implemented with reduction of travel time as a primary goal. The Automated Traffic Surveillance and Control (ATSAC) program in Los Angeles, California, largely a computerized signal control system, reported ***an 18% reduction in travel time, a 16% increase in average speed, and a 44% decrease in delay***[23]. The city of Toronto, Ontario, Canada, evaluated the SCOOT computerized signal control system on two corridors and the central business district network, totaling 75 signals[24]. During an evaluation performed over a two-month period comparing the SCOOT implementation to a "best effort" fixed timing plan, ***SCOOT resulted in a 8% decrease in travel time as well as a 17% decrease in delay.*** The City of Abilene, Texas, installed a closed-loop computerized signal system. Their report[25] ***indicates an overall decrease in travel time of 14%, a decrease in delay of 37%, and an increase in travel speed of*** 22%. Phase I of a Texas state program called Traffic Light Synchronization (TLS) involving 44 cities, has installed arterial and network signal system projects affecting 2,243 of the approximately 13,000 traffic signals in the state. An additional 73 systems were installed in phase II. TLS analysis shows a benefit/cost ratio of 62: [26], with a majority of the benefits being travel time reduction. ITE estimates of reduction in travel time from traffic signal improvements range from 8% to 25%[27].

Portland, Oregon[28] has integrated a bus priority system with the traffic signal system on a major arterial. ***By allowing buses to either extend green time or shorten red time by only a few seconds, the bus travel time was reduced by between 5% and*** 8%. In addition to the travel time savings, this approach allows the use of fewer vehicles to serve that route.

#### 2.1.2.2 Anecdotal Time Benefits of ATMS

The City of Richardson, Texas, tied the operator of the city's towing concession into the roadway surveillance network with an investment of roughly $200. Using the information provided by the camera, the tow truck dispatcher can position appropriate equipment near the collision site prior to the request for service from the police department. ***This reduces the***

**21** Smith, S. and Perez, C., "Evaluation of INFORM - Lessons Learned and Application to Other Systems," Conference Paper Presented at 71st TRB, January 1992.

**22** Robinson, J. and Piotrowicz, G., "Ramp Metering Status in North America, 1995 Update," Federal Highway Administration, June 1995.

**23** City of Los Angeles Department of Transportation, "Automated Traffic Surveillance and Control (ATSAC) Evaluation Study," June 1994.

**24** Siemens Automotive, USA, "SCOOT in Toronto," Traffic Technology International, Spring 1995.

**25** Orcutt Associates, "Evaluation Study, Buffalo Gap Road, Abilene Signal System," prepared for the City of Abilene, Texas, 1994.

**26** Benefits of the Texas Traffic Light Synchronization Grant Program I; Volume I, TxDOT/TTI Report #0258-l, Texas Department of Transportation, Austin, Texas, October 1992.

**27** Meyer, M., ed., A Toolbox for Alleviating Traffic Congestion, Institute of Transportation Engineers, Washington, DC, 1989.

**28** Kloos, W., et al., "Bus Priority at Traffic Signals in Portland: The Powell Boulevard Pilot Project," Submitted for ITE 1994 Compendium of Technical Papers, July 1994.

***response time for incident clearance by 5 - 7 minutes on average*** and greatly improves the ability to send appropriate equipment that can handle the active incident (Pamela Hadnot, City of Richardson internal memorandum, December 1995).

Fifteen authorities are currently using electronic toll collection (ETC), with more planning for implementations (Maureen Gallagher, IBTTA, telephone interview, February 1996). ETC can greatly improve throughput on a per-lane basis compared with manual toll collection techniques. On the Tappan Zee Bridge toll plaza, a manual toll lane can accommodate 350 - 400 vehicles per hour while an electronic lane peaks at 1000 vehicles per hour.

By replacing eight manual collection stations with five electronic lanes using the multijurisdictional E-ZPass electronic toll collection system, and implementing a movable barrier procedure to allow an extra peak direction lane, ***traffic speeds have increased from a crawling 8 - 12 mph to a flowing*** 25 ***mph*** (Mike Zimmerman, New York State Thruway Authority, telephone interview, December 1995). The nature of the data reported does not allow allocation of speed benefits between the electronic toll collection and moveable barrier solutions. (Information repeated in Section 2.4.2.1)

#### 2.1.2.3 Predicted Time Benefits of ATMS

Simulation and analysis have predicted that traffic adaptive signal controls could further reduce delays and emissions compared to the currently implemented systems under certain conditions. In simulations performed for the National ITS Architecture Program using non-proprietary adaptive algorithms, ***delay reductions of well over 20% were observed when traffic patterns deviated from predicted levels***[29].

### 2.1.3 Time Benefits of APTS

Public transportation systems can reduce travel time both by improving the operation of the vehicles and the overall operation of the transportation network. Vehicle management systems improve schedule adherence resulting in a reduction in passenger wait time and improvement in transfer coordination. To the extent that travel demand can be accommodated with higher occupancy vehicles, the transportation network is less congested, resulting in reduced travel time for both transit passengers and other vehicles.

#### 2.1.3.1 Measured Time Benefits of APTS

For nearly a decade, transit properties have been installing and using automatic vehicle location (AVL) systems based on signpost, triangulation, LORAN, and more recently GPS technologies.[30] The most direct improvement enabled by transit management systems relates to schedule adherence. The Mass Transit Administration in Baltimore, Maryland, reported a 23% improvement in on-time performance by AVL-equipped buses. ***The Kansas City Area Transportation Authority in and around Kansas City, Missouri, improved on-time performance by 12% in the first year of operation using AVL,*** compared to a 7% improvement as the result of

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29 Glassco, R., et al, "Studies of Potential Intelligent Transportation Systems Benefits Using Traffic Simulation Modeling," Mitretek Systems, MP96W0000101, March 1996.

30 Jones, W., ITS Technologies in Public Transit: Deployment and Benefits, USDOT ITS Joint Program Office, November 1995.

a coordinated effort between 1986 and 1989. ***Preliminary results from Milwaukee, Wisconsin, indicate a 28% decrease in the number of buses more than one minute behind schedule[31].***

#### 2.1.3.2 Anecdotal Time Benefits of APTS

AVL systems continue to be deployed rapidly. ***A recent study found 22 U. S. transit systems operating more than 7,000 vehicles under AVL supervision and another 47 in various stages of procurement.*** The new procurements represent a tripling of the number of deployed systems, with most new systems using a GPS-based location process[32]. Five Canadian operators are using AVL on fleets totaling 3700 buses, including a 2300-vehicle fleet in Toronto[33]. Fleet management systems with vehicle location capability are producing benefits in productivity, security and travel time. In addition, several operators have reported incidents where AVL information assisted in resolving disputes with employees and patrons.

### 2.1.4 Time Benefits of CVO

Implementation of ITS commercial vehicle services will reduce both travel time and regulatory time. Travel time of commercial vehicles can be reduced removing the need to stop at inspection stations and reducing processing times at ports of entry. Time required to acquire credentials and perform inspections could also be reduced with electronic communications and automated monitoring tools. Dispatch systems reduce time and telephone charges required for communications with dispatch centers.

#### 2.1.4.1 Measured Time Benefits of CVO

The Commercial Vehicle Operations (CVO) area continues to be viewed as a potential early winner for the ITS program. Use of advanced vehicle monitoring and communications technologies by motor carriers has demonstrated considerable time savings[34]. ***Schneider of Green Bay, Wisconsin, reported a 20% increase in loaded miles and that the elimination of driver check-in telephone calls saves approximately two hours per day resulting in a driver salary increase of $50 per week with a primary benefit of improved customer service. Trans- Western Ltd. of Lerner, Colorado, credits their-fleet management system for improved driver relations, noting that drivers are able to drive 50 to 100 additional miles per day. Frederick Trans ort of Dundas, Ontario, Canada, estimates an increase of 20% in loaded miles, a reduction of 30 from $150 per month in telephone charges, a 0.7% greater load factor and a 9% increase in total miles. Best Line of Minneapolis, Minnesota, estimates a $10,000 per month savings since 300 drivers previously lost about 15 minutes each day waiting to talk with dispatchers.*** (Information repeated in Section 253.1 and 2.6.3.1)

### 2.1.5 Time Benefits of AVCSS

Improved vehicle control can reduce travel time by allowing increased speeds and increased throughput at improved levels of safety. As sophistication of vehicle control systems progresses

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31 Giugno, M., Milwaukee County Transit System, July 1995 Status Report.

32 Casey, R. , and Labell, L., "Advanced Public Transportation Systems Deployment in the United States," USDGT Federal Transit Administration, August 1996.

33 Casey, R. et. al., Advanced Public Transportation Systems: The State of the Art - Update '96, USDGT Federal Transit Administration, January 1996.

34 Hallowell, **S.,** and Morlok, E., "Estimating Cost Savings From Advanced Vehicle Monitoring and Telecommunicating Systems in Intercity Irregular Route Trucking," Department of Systems, University of Pennsylvania, Philadelphia, PA, January 1992.

and as user confidence grows, significant speed increases are possible. Vehicle control systems aid indirectly in reducing non-recurrent congestion by reducing the number of incidents.

#### 2.1.5.1 Predicted Time Benefits of AVCSS

In a preliminary analysis performed for the Automated Highway System program, capacity increases of 300% for platooned operation and 200% for nonplatooned compared to current freeway operation have been predicted, yielding a reduction in delay related to congestion. ***Analysis based on the Long Island Expressway and the Capital Beltway near Washington, DC predicted that capacity improvements could reduce travel time by*** 38% ***to*** 48%[35]. (Information repeated in Section 2.4.3.1)

## 2.2 CRASHES

Reducing the number of crashes is an important aspect of improving safety. While the relationships between reduced crashes and other important statistics such as fatalities, injuries, and nonrecurrent delay vary with a number of factors, reducing crashes will tend to improve all of these statistics. Figure 3 shows the percentage reduction in crashes achieved in some operational systems. (Note: MCSAP refers to the Motor Carrier Safety Assistance Program.)

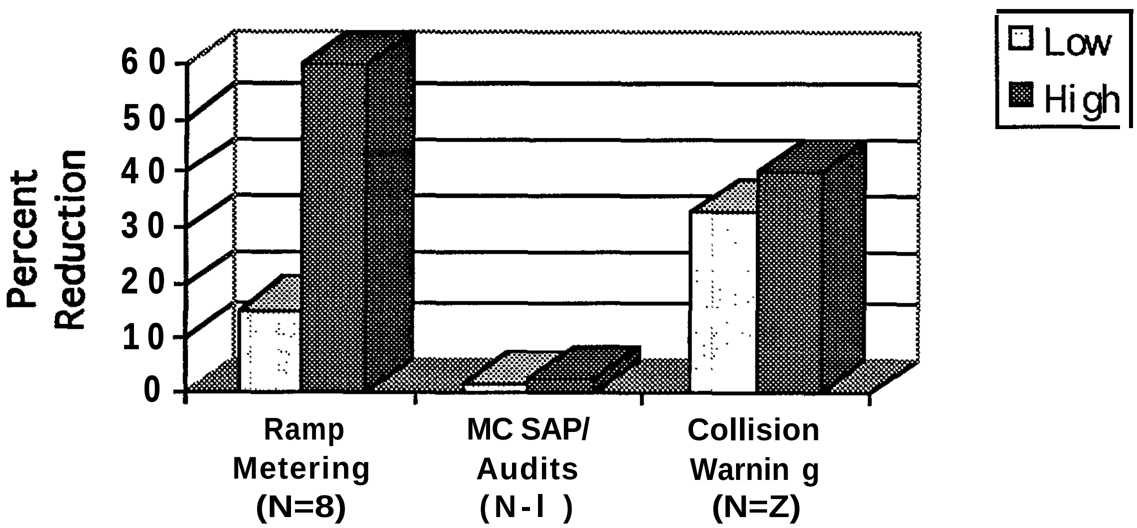


Figure 3 - Range of Measured Crash Reduction Benefits

### 2.2.1 Crash Reduction Benefits of ATIS

Traveler information systems can improve safety primarily by helping drivers avoid situations where risks of crashes are greater due to environmental, roadway, or traffic conditions. Tests to demonstrate such benefits are in the developmental and operational phases. Traveler information

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35 Stevens, W. et al., "Summary and Assessment of Findings from the Precursor Analyses of Automated Highway System," The MITRE Corporation, WN95W0000124, October 1995.

is expected also to improve safety by reducing distractions to the driving task due to route finding and navigation activities and smoothing the flow of traffic.

#### 2.2.1.1 Anecdotal Crash Reduction Benefits of ATIS

The safety potential for an advanced traffic information system that warns commercial vehicles and other heavy vehicles of a potentially dangerous highway situation is being tested. The Dynamic Truck Speed Warning System for Long Downgrades has been installed on I-70 west of the Eisenhower Tunnel west of Denver. This system warns drivers of safe truck speed at the start of the downgrade for normal operations based on the truck's measured weight. The Colorado Motor Carrier Association is excited about the potential for improved safety represented by this system. Prior to the project, the state studied accident characteristics and hypothesized that since 88% of the runaway trucks were out-of-state, many truck drivers were unfamiliar with the terrain. The fact that runaway truck drivers entered ramps at speeds of up to 110 mph supports this hypothesis (Greg Fulton, Colorado DOT, telephone interview, January 1995). The system began operating during 1995. ***While evaluation results are not yet available, observers report that trucks being instructed to slow frequently apply their brakes immediately.*** (Information repeated in Section 2.2.3.2)

The TravTek project examined the safety aspects of an in-vehicle navigation device that used a moving map display as well as voice directions. While data on accidents and near accidents are not statistically significant, driver workload studies yielded encouraging results. ***Compared to control conditions of paper maps and road signs, use of both visual and voice displays yielded lower driver workloads in each category of stress including time stress, visual effort, and psychological stress***[36] TravTek users also perceived that they were safer.

#### 2.2.1.2 Predicted Crash Reduction Benefits of ATIS

The TravTek project used a simulation approach to estimate safety impact. Using the INTEGRATION simulation model, a representation of the Orlando roadway network, and performance parameters obtained during the live field studies, analyses were performed to estimate crash risk of motorists using navigation devices compared to motorists without them. In addition, the safety impacts on the entire traffic network (both equipped and unequipped vehicles) were analyzed. Results indicated an overall reduction in crash risk of up to 4% for motorists using navigation devices, due to improved wrong turn performance and the tendency of the navigation system to route travelers to higher class (normally safer) facilities. Other indications from the TravTek field studies were that the ability of the navigation system to receive real-time traffic and congestion information provided an advance warning to motorists of potentially unsafe conditions on the route they were traveling, further improving the safety benefits of the system. The simulations showed a potential for increased safety risk for navigation-system-equipped vehicles when real-time information caused them to divert from a higher class facility to a lower class road (e.g., from a freeway to an arterial). Increased safety risks of up to 10% were estimated for the equipped vehicles, while the overall network showed a safety neutral to a slight safety improvement when diversion occurred. The network safety improvements were experienced when diversion from congested roadways reduced the level of congestion for the remaining equipped and non-equipped vehicles and helped to smooth traffic flows on those roads.

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36 Inman, V., et. al., "TravTek Evaluation: Orlando Test Network Study," FHWA-RD-95-162, Federal Highway Administration, January 1996.

### 2.2.2 Crash Reduction Benefits of ATMS

Traffic management systems reduce accidents primarily by limiting the conflict of streams of traffic either by installing traffic control devices or improving compliance with those devices.

#### 2.2.2.1 Measured Crash Reduction Benefits of ATMS

The first ramp meter was installed on the Eisenhower Expressway in Chicago in 1963. Other early adopters of freeway ramp meters include Detroit, Michigan, Minneapolis, Minnesota, and Los Angeles, California. By 1989, the Federal Highway Administration (FHWA) had enough data to put together a summary of ramp metering practices with quantitative results. As places such as Minneapolis upgrade their ramp metering systems into true Freeway Management Systems, results continue to improve along with coverage, capability, and coordination. While ramp metering systems are designed to improve operation at the merge point to improve mainline speed and capacity, field experience has demonstrated a significant reduction in accident rate. ***According to Minnesota DOT Freeway Operations Meeting Minutes from January of 1994, accident rates on I-35W in Minneapolis before management were 421 per year and are now 308per year (a 27% reduction). Annual accident experience on the same freeway after management is 2.1 I collisions per million vehicle miles traveled (VMT) compared to 3.40 collisions per million VMT before management was instituted (a 38% reduction).*** A longitudinal study of the ramp metering/freeway management system in the Seattle, Washington, area over a six year period[37] shows that ***accident rates have fallen consistently to a current level of*** 62% ***compared to the base period.*** A survey of traffic management centers using ramp metering[38] reported similar findings. ***Accidents on freeway systems underfreeway management were reduced between 15% and*** 50%. While some other freeway improvements were implemented during the study periods, the combination of geometric, vehicle, and operational procedures showed significant reductions in accident rate.

The reduction in secondary collisions attributable to the incident management program, which may be quite significant, is difficult to estimate due to the coordinated freeway management program in the area. However, an analysis of the accident statistics on several California arterials and expressways shows that secondary accidents represent an increase in accident risks of over 600%[39] without controlling for climatic or other conditions. Another California freeway study[40] placed the increase in collision rate at 300% in congested conditions on average, with variance due to geometric conditions. The CHART evaluation estimates that the traffic management center, including freeway service patrols, was responsible for a 5% reduction in the number of accidents during non-recurrent congestion.

The use of video surveillance for traffic law enforcement is a more controversial area of potential benefits derived from ITS. A few pilot studies are in place in the United States, such as a signal compliance device in New York City. European countries have been more willing to use automated enforcement devices. ***Installation of speed enforcement cameras in London have reduced speed by approximately 10%, accidents by 20% to as much as 80% and serious injuries***

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37 Henry, K. and Meyhan, 0., "6 Year FLOW Evaluation," Washington State DOT, District 1, January 1989.

38 Robinson, J. and Piotrowicz, G., 'Ramp Metering Status in North America, 1995 Update," Federal Highway Administration, June 1995.

39 Intelligent Transportation Systems Impact Assessment Framework: Final Report, Volpe National Transportation Systems Center, September 1995.

40 Sullivan, E. C., and Hsu, C-I. "Accident Rates Along Congested Freeways: Final Report," Research Report UCB-ITS-RR-88-6, Institute of Transportation Studies, University of California, Berkeley, CA, 1988.

***andfatalities by about 50%.*** An additional benefit is that 98% of all parties intended for prosecution are not contesting the citations[41].

#### 2.2.2.2 Anecdotal Crash Reduction Benefits of ATMS

Highway-railroad grade crossing systems were recently added to the ITS program. The need for improvement is indicated by the fact that in 1992, 577 fatalities and 1963 injuries occurred at grade crossings[42] Additionally, the occasional spectacular accident including school children or hazardous materials attract national attention. Several technologies are currently being tested including photo enforcement and adaptation of collision warning systems. ***Initial tests of photo enforcement in Los Angeles have yielded positive results, with a 92% decrease in violation rate.*** Since the deployment is limited and grade crossing accidents are relatively rare, the fact that no accidents occurred during the test is not statistically significant (Dana King, U. S. Public Technologies Inc., personal interview, January 1996).

### 2.2.3 Crash Reduction Benefits of ARTS

Rural applications that reduce crashes are either information systems or vehicle control systems. Rural information systems inform travelers of potential hazards which may pose a crash threat. Vehicle control systems are intended to reduce the probability of crashes. Crashes, such as those in roadway departures, are more prevalent in rural areas and are particular targets for rural applications of advanced vehicle control systems.

#### 2.2.3.1 Measured Crash Reduction Benefits of ARTS

Collision warning devices and blind spot detectors are becoming available as commercial products. Transport Besner Trucking Co. has installed an Eaton-Vorad collision warning device on 100% of its 170 truck fleet. ***Internal studies found that the combination of the device with a safety training program has reduced accidents by*** 33% (Daniel Lareau, Transport Besner Trucking Company, telephone interview, February 1996 verifying information in "Freightliner to Offer Collision Warning on New Truck Line," Inside ITS, Vol. 5, No. 23, November 20, 1995). ***The Greyhound accident experience using an earlier model product yielded a reduction of*** 20% ***in a deployment equipping half of the fleet,*** which could extrapolate to a 40% reduction in accidents for full equipage[43]. (Information repeated in Section 2.2.5.1)

#### 2.2.3.2 Anecdotal Crash Reduction Benefits of ARTS

In addition to the quantitative results from the collision warning systems, other installations and pilot projects are taking place. Landstar Systems is installing the Eaton-Vorad system on 40% of its owned fleet and giving the contract fleet incentive to equip. Positive evaluation of the device by experienced drivers in a pilot test and the potential to decrease self insurance losses lead to the decision to equip. ***While Landstar does not have reliable statistics, no equippedpower units have been involved in a rear-end collision since the installation began in January of 1995*** (Brian Kinsey, Landstar Systems, telephone interview, February 1996). (Information repeated in Section 2.2.5.2)

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41 Harris, J. and Sands, M., "Speed Camera Advances," Traffic Technology International, Spring 1995.
42 National Transportation Statistics Annual Report, USDOT Bureau of Transportation Statistics, U. S.
43 Government Printing Office, Washington, DC, September 1993.
Renforth, James D., Director - Safety Services of Greyhound Lines, Inc., letter to Paul Bouchard, President, VORAD Safety Systems, February 1994.

The safety potential for an advanced traffic information system that warns commercial vehicles and other heavy vehicles of a potentially dangerous highway situation is being tested. The Dynamic Truck Speed Warning System for Long Downgrades has been installed in the Eisenhower Tunnel on I-70 west of Denver. This system warns drivers of safe truck speed at the start of the downgrade for normal operations based on truck weight. The Colorado Motor Carrier Association is excited about the potential for improved safety represented by this device. Prior to the project, the state studied accident characteristics and discovered that 88% of the runaway trucks were out-of-state and that they entered runaway truck ramps at speeds of up to 110 mph (Greg Fulton, Colorado DOT, telephone interview, January 1995). The system began operating during 1995. ***While evaluation results are not yet available, observers report that trucks being instructed to slow frequently apply their brakes immediately.*** (Information repeated in Section 2.2.1.1)

#### 2.2.3.3 Predicted Crash Reduction Benefits of ARTS

Automated Highway System (AI-IS) related products can have safety benefits prior to full implementation of AHS segments. Based on data from Minnesota[44],60% of rural freeway accidents are susceptible to reduction using lane keeping and collision avoidance technologies. These types of collisions include run-off-the-road, accounting for 34% of accidents, and animal hits. ***A reduction of 40% in these accidents could account for an annual reduction of*** 19,000 ***accidents including 190 fatal accidents nationally accounting for an estimated cost savings of $225 million.*** (Information repeated in Section 2.2.5.3)

A group has been convened by NHTSA to examine the expected benefits of collision avoidance systems. This working group is examining the number of crashes that can be avoided using in-vehicle devices to aid in avoiding lane change/merge, rear end, and single-vehicle roadway departure crashes. ***Based on the best experimental data available, use of these devices could avoid a total of 1.1 million crashes annually***[45]. (Information repeated in Section 2.2.5.3)

### 2.2.4 Crash Reduction Benefits of CVO

Commercial vehicle operations can directly reduce the number of crashes by improving the identification of drivers and vehicles that are at high risk using in-vehicle, deskside, and roadside systems. While these automated CVO safety systems are not fully in place yet, experience with existing programs indicates significant potential benefits. The improvement in traffic flow near weigh stations and enforcement areas with the implementation of CVO systems may also contribute to a reduction in crashes.

#### 2.2.4.1 Anecdotal Crash Reduction Benefits of CVO

***An early information network in Oregon enabled an increase of 90% in number of weighings and 428% in number of safety inspections between 1980 and I989 while staff increased by only*** 23%[46]. While these measures are not directly of desired outcomes, the link between inspections and reductions in crashes is intuitive.

44 AHS Precursor Analyses, Activity Area A, Urban and Rural AHS Analysis, Battelle, BRW, and Transportation Research Center, 1994.

45 Recht, P., NHTSA, Presentation at the ITS America Sixth Annual Meeting, April 1996.

46 Krukar, M. and Evert, K., Integrated Tactical Enforcement Network (Automated Enforcement Facilities in Oregon), Presented at the National Traffic Data Acquisition Technologies Conference, Austin, TX, 17 -20 August 1990.

#### 2.2.4.2 Predicted Crash Reduction Benefits of CVO

ITS implementation is expected to improve the safety record of motor carriers. Electronic screening and improved inspection procedures will help to eliminate major causes of accidents through better use of communications and information technology. Evidence of future success is indicated by ongoing motor carrier safety programs including the Motor Carrier Safety Assistance Program (MCSAP) and federal safety audits. ***The benefit/cost ratio of these programs has been estimated as 2.5 while yielding a reduction of 2,500 – 3,500 accidents annually[47].***

### 2.2.5 Crash Reduction Benefits of AVCSS

There are a number of vehicle control systems available that are designed to reduce the likelihood of crashes. These systems either test the facility of the driver, improve the awareness of the driver, or take direct control of the vehicle in certain circumstances in order to assist in avoiding the crash. Initial devices that improve the awareness of the driver are currently available as commercial products and are beginning to report benefits.

#### 2.2.5.1 Measured Crash Reduction Benefits of AVCSS

Collision warning devices and blind spot detectors are becoming available as commercial products. Transport Besner Trucking Co. has installed an Eaton-Vorad collision warning device on 100% of its 170 truck fleet. ***Internal studies found that the combination of the device with a safety training program has reduced accidents by*** 33% (Daniel Lareau, Transport Besner Trucking Company, telephone interview, February 1995 verifying information in "Freightliner to Offer Collision Warning on New Truck Line," Inside ITS, Vol. 5, No. 23, November 20, 1995). ***The Greyhound accident experience using an earlier model product yielded a reduction of 20% in a deployment equipping half of the fleet,*** which could extrapolate to a 40% reduction in accidents for full equipage[48]. (Information repeated in Section 2.2.3.1)

#### 2.2.5.2 Anecdotal Crash Reduction Benefits of AVCSS

In addition to the quantitative results from collision warning systems, other installations and pilot projects are taking place. Landstar Systems is installing the Eaton-Vorad system on 40% of its owned fleet and giving the contract fleet incentive to equip. Positive evaluation of the device by experienced drivers in a pilot test and the potential to decrease self insurance losses lead to the decision to equip. ***While Landstar does not have reliable statistics, no equipped power units have been involved in a rear-end collision since the installation began in January of*** 1995 (Brian Kinsey, Landstar Systems, telephone interview, February 1996). (Information repeated in Section 2.2.3.2)

Another collision avoidance product, which has been in use since 1993, is the Forewarn system applied to school buses. In 1992 - 1994, of the 25 - 40 school-age children killed by buses, over two-thirds were as pedestrians at the time[49,50,51]. Many of these children had either just exited the

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47 Moses, L. and Savage, I., "A Cost-Benefit Analysis of the Federal Motor Carrier Safety Programs, 3rd Version," Department of Economics and the Transportation Center, Northwestern University, Evanston, IL, 1993.

48 Renforth, James D., Director - Safety Services of Greyhound Lines, Inc., letter to Paul Bouchard, President, VORAD Safety Systems, February 1994.

49 National Highway Traffic Safety Administration, "Traffic Safety Facts 1992 (Revised)," DOT-HS-808-022, March 1994.

bus or were waiting to board it. ***Although quantitative benefits are not yet available, pilot programs in states considering deployment of such a device have gone exceptionally well, with many drivers having stories of situations in which the system told them of the presence of children who were in harm's way*** (Jeff Himelick, Delco Electronics, telephone interview, March 1995). As of late 1995, about 500 of the devices were in active use (Ed Cannard, Delco Electronics, telephone interview, December 1995).

#### 2.2.5.3 Predicted Crash Reduction Benefits of AVCSS

Automated Highway System (AHS) related products can have safety benefits prior to full implementation of AHS segments. Based on data from Minnesota[52], 60% of rural freeway accidents are susceptible to reduction using lane keeping and collision avoidance technologies. These types of collisions include run-off-the-road, accounting for 34% of accidents, and animal hits. ***A reduction of 40% in these accidents could account for an annual reduction of*** 19,000 ***accidents including 190 fatal accidents nationally accounting for an estimated cost savings of $225 million.*** Applying the same type of analysis to urban areas shows the most common types of accidents to be rear end (50%), run-off-the-road (22%), and side swipe (13%). These also are susceptible to correction with less than full implementation of AHS. ***Assuming a reduction of 35% of these accidents, 52,000 fewer collisions could be expected to occur on a national basis, including 100 fatal accidents.*** (Information repeated in Section 2.2.3.3)

A group has been convened by NHTSA to examine the expected benefits of collision avoidance systems. This working group is examining the number of crashes that can be avoided using in-vehicle devices to aid in avoiding lane change/merge, rear end, and single-vehicle roadway departure crashes. ***Based on the best experimental data available, use of these devices could avoid a total of 1.1 million crashes annually.***[53] (Information repeated in Section 2.2.3.3)

## 2.3 FATALITIES

Since a fatality resulting from a crash can be prevented if the crash is avoided, systems that reduce the number of crashes also reduce fatalities. In addition, systems that reduce the severity of the crash, the consequences of the crash, or emergency medical services response times to victims of the crash also reduce the number of fatalities and the extent of injuries. The following sections discuss the reduction of injuries and fatalities and do not reiterate the benefits related to reducing just the number of crashes.

### 2.3.1 Fatality Reduction Benefits of ATIS

In addition to helping avoid crashes, information in the form of traffic conditions and route guidance provided to emergency service providers can reduce the time between a request for service and the arrival of the service at the required location.

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51 National Highway Traffic Safety Administration, "Traffic Safety Facts 1993," DOT-HS-808-169, October 1994.

51 National Highway Traffic Safety Administration, "Traffic Safety Facts 1994," DOT-HS-808-292, August 1995.

52 AHS Precursor Analyses, Activity Area A, Urban and Rural AHS Analysis, Battelle, BRW, and Transportation Research Center, 1994.

53 Recht, P., NHTSA, Presentation at the ITS America Sixth Annual Meeting, April 1996.

#### 2.3.1.1 Anecdotal Fatality Reduction Benefits of ATIS

AVL/CAD and navigation systems are being installed in fire, police, and emergency vehicles. While quantitative evaluations are rare, a collection of anecdotal evidence is becoming available. A crash in Muskogee County, Oklahoma, involving a car and a school bus, resulted in the need for medical attention. The fog that contributed to the collision would have also delayed an ambulance and made location of the collision difficult from a helicopter. However, the helicopter, equipped with a GPS receiver, located the crash scene using location information provided by a Highway Patrol officer on the scene using a handheld GPS. The helicopter was then able to complete the rescue[54]. The AVL system installed by the Schaumburg, Illinois police department has been reported to enable dispatch of backup to officers who failed to report location information and dispatch of assistance to an incapacitated office[55].

### 2.3.2 Fatality Reduction Benefits of ARTS

In addition to the avoidance of difficult driving situations, rural transportation systems can reduce the consequences of crashes by means of emergency notification systems. Commercial systems are available that couple mobile telephone technology with satellite navigation. Operational tests of additional systems sponsored by the federal government are ongoing.

#### 2.3.2.1 Predicted Fatality Reduction Benefits of ARTS

According to analysis based on data from the Fatal Accident Reporting System, reduction of incident notification times on rural highways from the current average of 9.6 minutes to 4.4 minutes, corresponding to mayday devices working properly in 60% of rural crashes, ***would result in a reduction in fatalities of 7% annually, or a national total of 1727***[56]. A reduction to 1 minute, corresponding to mayday devices working properly in 100% rural crashes, would reduce fatalities by 3069 annually nationwide, or 12%. As of April 1996,200 units of the Lincoln RESCU mayday-type system, available as an option on the Continental, were in use by consumers and half of factory orders requested an introductory package the included the RESCU system[57].

### 2.3.3 Fatality Reduction Benefits of CVO

Although crash statistics indicate that commercial vehicle drivers are involved in fewer accidents per mile traveled than the average vehicle, the larger number of miles driven on an annual basis and the increased risk of injury when crashes do occur result in high levels of responsibility on the part of the commercial vehicle operator and regulator. Commercial vehicle operations can directly reduce the number of crashes by improving the identification of drivers and vehicles that are at high risk using in-vehicle, deskside, and roadside systems and thereby reduce the number of fatalities.

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54 "GPS Aids in Oklahoma Bus Crash," Earth Observation Magazine, April 1996.
55 Pilant, L., "Automated Vehicle Location," The Police Chief, September 1995.
56 Evanco, W., "Reducing Accident Fatalities with Rural Mayday Systems," Mitretek Systems, Inc., WN96WO000048, April 1996.
57 Duncan, D., Ford Motor Company, Presentation made at the ITS America Sixth Annual Meeting, April 1996.

#### 2.3.3.1 Predicted Fatality Reduction Benefits of CVO

Analysis using empirical data to estimate the impact of CVO implementation on fatal involvements found a potential reduction of 14% to 32%[58]. The analysis considered experience reported relating total miles traveled, percentage of rural travel, and inspection practices to fatality rate. The impact was estimated using predicted usage of CVO services and changes in inspection practices due to ITS CVO implementation.

### 2.3.4 Fatality Reduction Benefits of AVCSS

Pre-crash restraint deployment systems are expected to reduce injuries and fatalities by protecting vehicle passengers better than current technology. The same vehicle control systems that reduce the likelihood of crashes, reduce the severity of crashes by reducing the vehicle speed at the time of the crash and therefore the energy of the collision. Although initial devices that improve the awareness of the driver are currently available as commercial products, data on reduced fatalities are not available. Devices that automatically notify emergency service providers that a crash has occurred can reduce fatalities by summoning medical help more quickly.

#### 2.3.4.1 Anecdotal Fatality Reduction Benefits of AVCSS

In Stuttgart, Germany, tests of an on-board crash notification system, simulated emergency calls have shown a decrease in time for medical help to arrive from 14 minutes to 8 minutes for urban crashes and from 21 minutes for out-of-town crashes. The 43% drop in response time corresponds to a 12% increase in the chance of survival for an occupant involved in the crash[59]. For comparison purposes, US response times for fatal accidents average 10.1 minutes in urban areas and 19.6 minutes in rural areas[60].

### 2.3.5 Fatality Reduction Benefits of Integrated Systems

Incorporation of multiple services into a single center is expected to provide benefits in operational and organizational arenas. While few quantitative results are available from such centers, individual occurrences as well as the continued development of such centers indicates perceptible benefits.

#### 2.3.5.1 Anecdotal Fatality Reduction Benefits of Integrated Systems

The San Antonio TransGuide facility opened in the summer of 1995. The value of an integrated facility was demonstrated in the week before the center opened when an industrial plant fire erupted within view of freeway video surveillance. ***Based on the visibility afforded at TransGuide, the fire was accessed and fought more effectively, possibly saving the lives of several fireflghters.*** Both local police and fire were convinced of the wisdom of their investment in collocation.

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58 Evanco, W., "The Impact on Fatal Involvements of Commercial Vehicle Operation ITS Services," Mitretek Systems, Inc., unpublished draft.

59 "Stuttgart STORMS Ahead," Intelligent Transport Systems, Issue No. 2, Kent, UK, Autumn 1995.

60 National Highway Traffic Safety Administration, "Traffic Safety Facts 1994," DOT-HS-808-292, August 1995.

#### 2.3.5.2 Predicted Fatality Reduction Benefits of Integrated Systems

According to analysis similar to the rural analysis reported earlier based on data from the Fatal Accident Reporting System, reduction of incident notification times on urban interstates from the current average of 5.2 minutes to 2 minutes ***would result in a reduction in fatalities of 15%, or a national total*** of 356 ***lives annually*** if all urban interstates nationwide were under such a program[61]. A reduction to three minutes would reduce fatalities by 246 annually nationwide, or 11%. For comparison, the San Antonio TransGuide project has an incident detection goal of two minutes[62].

## 2.4 THROUGHPUT

Many ITS components seek to optimize use of existing facilities and right-of-ways so that mobility and commerce needs can be met while reducing the need to construct new facilities or expand right-of-ways. One approach is to improve throughput in number of people, number of vehicles, or amount of goods moved per unit of time while maintaining or improving level of service. Although some ITS components address throughput of individual facilities, other components seek to improve network throughput, which is more difficult both to define and to measure. Figure 4 shows the percentage increases in maximum throughput achieved in operational systems and increases in throughput expected using collision avoidance systems.

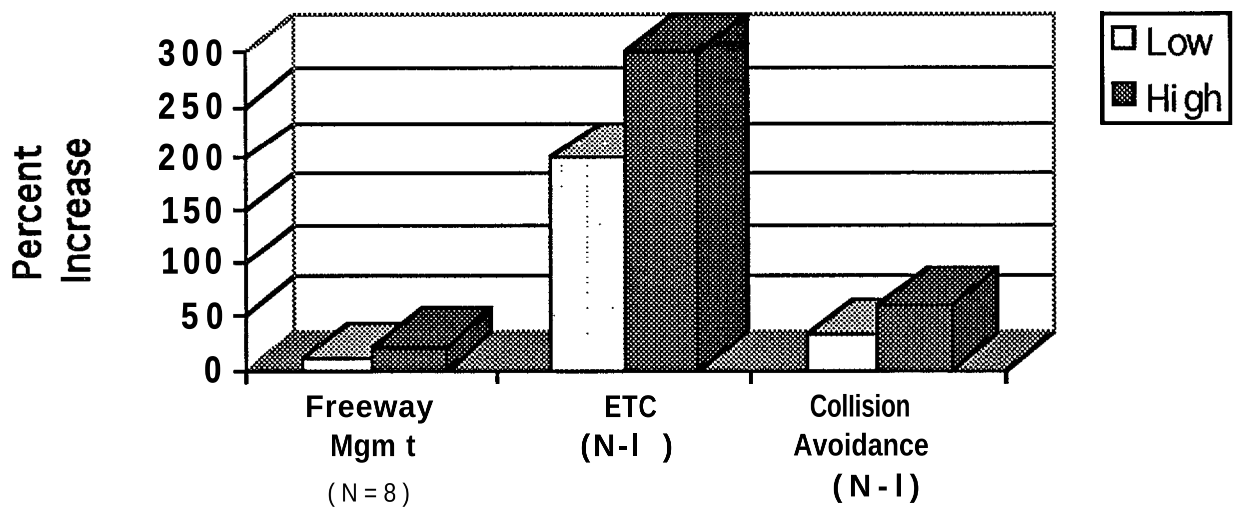


Figure 4 - Ranges of Throughput Improvement Benefits

### 2.4.1 Throughput Benefits of ATIS

Traveler information systems can increase the throughput of existing facilities by informing travelers to make better decisions. Information regarding incidents and congestion allows

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61 Evanco, W., "The Impact of Rapid Incident Detection on Freeway Accident Fatalities," Mitretek Systems, Inc., WN96WOOOOO7 1, June 1996.

62 McGowan, P. and Irwin, P., "TransGuide Transportation Guidance System: Technology in Motion," Texas DOT, November 1995.

vehicles to reroute onto less congested facilities and, to the extent that information leads travelers to share rides in carpools or transit, will increase the average occupancy of the vehicles on the network. Route guidance information will reduce the amount of distance traveled due to poor navigation, thereby increasing effective capacity of the network. Although studies relating traveler information to decreased travel time give an indication of increased throughput, no quantitative estimates of network improvements are currently available.

#### 2.4.1.1 Predicted Throughput Benefits of ATIS

Simulation using data collected during the TravTek test predicted a benefit in throughput. Using constant average trip duration as a surrogate for maintaining level of service, a market penetration of 30% for dynamic route guidance results in the ability to handle 10% additional demand[63].

### 2.4.2 Throughput Benefits of ATMS

Traffic management systems improve throughput by improving the flow of traffic both in incident and nonincident conditions, similar to the manner by which travel time is decreased. By using improved communications and control techniques, traffic management can adjust control devices to improve utilization of available capacity in congested or incident situations and can respond more quickly to incidents to restore full capacity.

#### 2.4.2.1 Measured Throughput Benefits of ATMS

Freeway management systems including both ramp meters and incident management programs are designed to improve the operating performance of freeways. Maximum throughput is reported in the freeway operations meeting minutes as 2200 vplph compared with 1800 prior to the use of the ramp meters while average speeds have risen from 34 MPH to 46 MPH according to the Minnesota DOT meeting notes. The Seattle, Washington study[64] showed a ***growth in traffic of 10% to 100% along various segments of I-5 while speeds have remained steady or increased up to 20%. Other ramp metering installations have reported increases in peak throughput of 8% - 22% with steady or increased travel speed,***[65] (Information repeated in Section 2.1.2.1)

Throughput of an electronic toll collection lane can exceed that of a staffed lane by 200 - 300%. ***On the Tappan Zee Bridge toll plaza, a manual lane can accommodate 350 - 400 vehicles per hour while an electronic lane peaks at 1000 vehicles per hour.*** By replacing eight manual collection stations with five electronic lanes using the multijurisdictional E-ZPass system, and implementing a movable barrier procedure to allow an extra peak direction lane, traffic speeds have increased from a crawling 8 - 12 mph to a flowing 25 mph (Mike Zimmerman, New York State Thruway Authority, telephone interview, December 1995). The New York State Thruway, which includes the Tappan Zee Bridge, benefits significantly from ETC in that expansion beyond 13 lanes for the toll plaza was not an option and the toll authority had implemented tandem operations on 5 of the lanes. (Information repeated in Section 2.1.2.1)

63 Van Aerde, M., and Rakha, H., "TravTek Evaluation: Modeling Study," FHWA-RD-95O?O, Federal Highway Administration, March 1996.

64 Henry, K. and Meyhan, 0.. "6 Year FLOW Evaluation," Washington State DOT, District 1, January 1989.

65 Robinson, J. and Piotrowicz, G., "Ramp Metering Status in North America, 1995 Update," Federal Highway Administration, June 1995.

## 2.4.3 Throughput Benefits of AVCSS

Improved vehicle control can increase throughput at improved levels of safety by reducing required headway. Indirectly, vehicle control systems aid in reducing throughput decreases related to incidents by reducing the number of incidents.

### 2.4.3.1 Predicted Throughput Benefits of AVCSS

In preliminary analysis performed for the Automated Highway System, ***throughput increases of 300% for platooned operation and 200% for nonplatooned compared to freeway segments have been predicted***[66]. Less complete implementations, termed evolutionary representative system configurations with rear-end collision warning or collision avoidance can show less dramatic capacity increases of 30% with collision warning in uniform vehicles to 60% with collision avoidance in vehicles differing in braking capacity by up to 0.25g[67]. (Information repeated in Section 2.1.5.1)

## 2.5 COST

Implementing ITS requires funding. However, frequently ITS implementation reduces operating costs and allows productivity improvements. In addition, ITS options may have lower acquisition costs compared to traditional transportation improvement options, and may have lower life-cycle costs due to operating cost and productivity improvements. Figure 5 shows percentage improvement in operating costs and productivity.

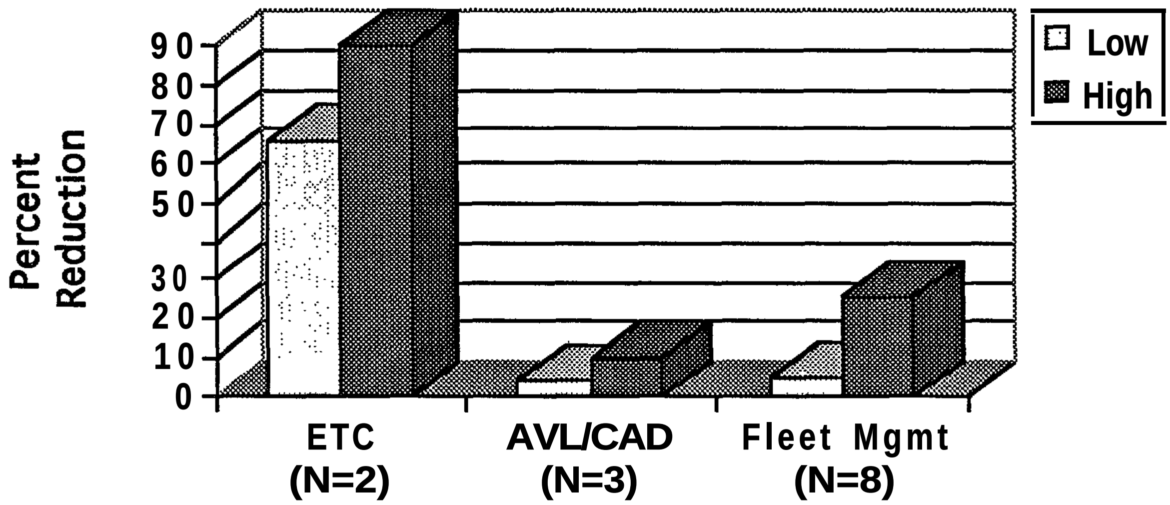


Figure 5 - Range of Experienced Improvement in Operating Costs and Productivity

66 Stevens, W. et al., "Summary and Assessment of Findings from the Precursor Analyses of Automated Highway System," The MITRE Corporation, WN95W0000124, October 1995.

67 "Precursor Systems Analyses of Automated Highway Systems: Volume Four - Lateral and Longitudinal Control Final Report," prepared by University of Southern California Center for Advanced Transportation Technologies under subcontract to Raytheon Company for Federal Highway Administration, February 1995.

### 2.5.1 Cost Reduction Benefits of ATMS

Traffic management systems can reduce costs by reducing labor costs to operate facilities. The cost to the infrastructure provider of maintaining a desired level of service can be lowered by increasing vehicle capacity of existing facilities at a lower cost than traditional options such as additional lanes or new construction.

#### 2.5.1.1 Measured Cost Reduction Benefits of ATMS

Deployment of ETC is occurring at a rapid pace and is being driven by cost savings to the operator. The Oklahoma Turnpike has been operating ETC in the Pike Pass program for over five years with excellent results ***Statistics from the Turnpike in a flyer entitled Pike*** Pass ***Facts indicate a 91% savings:***

Annual cost to operate automated lane - $15,800
Annual cost to operate an attended lane - $176,000.

### 2.5.2 Cost Reduction Benefits of APTS

Public transportation applications can reduce the cost of transit operation by improving productivity of staff and utilization of facilities and equipment.

#### 2.5.2.1 Measured Cost Reduction Benefits of APTS

The use of AVUCAD systems has demonstrated significant productivity improvements to transit operators. In Kansas City, Missouri, the analysis of actual run times on all routes over an extended period of time allowed a reduction in equipment requirement in several routes of up to 10%, allowing fewer buses to serve those routes with no reduction in service to the customer. The result was a savings in both operating expense and capital expense by actually removing these buses from service and not replacing them. ***The productivity gain of eliminating seven buses out of a 200 bus system allowed Kansas City to amortize their investment in AVL in two years. Other transit systems have reported reductions in fleet size of 4% to 9% due to efficiencies of bus utilization***[68].

The Winston-Salem Transit Authority in Winston-Salem, North Carolina, evaluated effects of a computer-aided dispatch and scheduling (CADS) system[69] in operation of a 17 bus fleet. ***While the client list grew from 1,000 to 2,000 over a &month period and vehicle miles per passenger trip grew 5%, operating expenses dropped 2% per passenger trip and 9% per vehicle mile.*** These productivity improvements occurred at the same time as service improvements including institution of same day reservations, which grew to account for 10% of trips, and a decrease in passenger wait time of over 50%.

While much of the literature regarding electronic fare payment discusses technical capability and patron convenience, some early indications of benefits to the transit property are accumulating[70]. ***Reduced fare evasion has increased revenue from 3% to 30%. Reductions in data collection cost range from an estimated $1.5 million in Manchester, UK to a predicted $5 million in Ventura, California, in addition to improved data accuracy. New York estimates the increase in ridership***

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68 Jones, W., ITS Technologies in Public Transit: Deployment and Benefits, USDOT ITS Joint Program Office, November 1995.

69 Stone, J., "Winston-Salem Mobility Management: An Example of APTS Benefits," NC State University, Interim Report, 1995.

70 Dinning, M., "Benefits of Smart Cards in Transit," draft, The Volpe Center, September 1995.

***due to electronic fare payment to be worth $49 million. New Jersey Transit estimates annual cost reduction of $2.7 million in cash handling while Atlanta estimates $2 million in savings[71].***

Public transportation providers in rural areas can produce cost efficiencies by increasing ridership. The computer-assisted dispatching system in Swectwater County, Wyoming, which allows same-day ride requests to be accepted, has contributed to an increase in ridership from 5,000 passengers monthlyto 9,000 monthly without increasing the dispatch staff and a reduction of operational expense of 50% over a 5-year period on a per passenger mile basis[72].

#### 2.5.2.2 Predicted Cost Reduction Benefits of APTS

Analysis of benefits accruing to the transit industry from APTS technologies predicts that current and planned deployments at US transit properties will yield benefits totaling between $3.8 billion and $7.4 billion in discounted 1996 dollars over the next ten years. In approximate terms, 44% of the total results from transit management systems, 34% from electronic fare payment systems, 21% from automated traveler information systems, and 1% from computer-aided dispatching in demand-responsive transit application[73].

Public transportation providers in rural areas can coordinating travel needs among various providers. The Potomac and Rappahannock Transportation Commission operates a demand-responsive transit to serve transit needs and commuter rail stations in the suburban fringe of the Washington, DC, metropolitan area. The service also meets requirements of the Americans with Disabilities Act. Compared to a fixed route service and complementary paratransit service, the demand-responsive system estimates a 40% reduction in total cost[74]. Use of coordinated paratransit with a dispatch system including AVL, which can coordinate trips among up to five agencies, has the potential to reduce fraud in Medicaid transportation by $11 million annually in the State of Florida[75].

### 2.5.3 Cost Reduction Benefits of CVO

Commercial vehicle operations can reduce costs to both the regulators and the motor carriers by automating paperwork completion and improving the productivity of employees and utilization of facilities and equipment. Improved enforcement of regulation, especially weight regulations, can reduce infrastructure maintenance and replacement costs.

#### 2.5.3.1 Measured Cost Reduction Benefits of CVO

The CVO area continues to be viewed as a potential early winner for the ITS program. Productivity improvements reported by motor carriers (in a 1992 study) using advanced vehicle monitoring and communications technology provide an indication of the magnitude of these

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71 Jones, W., ITS Technologies in Public Transit: Deployment and Benefits, USDOT ITS Joint Program Office, November 1995.

72 Casey, R., "The Benefits of ITS Technologies for Rural Transit," The Volpe Center, presented at the Rural ITS Conference, September 1996.

73 Goeddel, D., "Benefits Assessment of Advanced Public Transportation Systems (APTS)", prepared for Federal Transit Administration by Volpe National Transportation Systems Center, July 1996.

74 Farwell, R., "Evaluation of OmniLink Demand Driven Transit Operations: Flex-Route Services," SG Associates, Annadale, Virginia, presented at the European Transport Forum, 1996.

75 Ride Solutions, "Operational Strategies for Rural Transportation," Florida Coordinated Transportation System, undated.

benefits[76]. For intercity irregular-route trucking, ***Telesat Canada estimates use of its system will increase loaded mileage 9% to 16% and reduce operating costs $.12 to $.20 per truck mile, Schneider of Green Bay, Wisconsin, reports a 20% increase in loaded miles and that the elimination of driver check-in telephone calls saves approximately two hours per day resulting in a driver salary increase of $50 per week with a primary benefit of improved customer service. Trans-Western Ltd. of Lerner, Colorado, credits their fleet management system for improved driver relations, noting that drivers are able to drive 50 to 100 additional miles per day and driver turn-over has decreased from 100% to 30%. Frederick Transport of Dundas, Ontario, Canada, estimates an increase of 20% in loaded miles, a reduction of $30 from $150 per month in telephone charges, a 0.7% greater load factor and a 9% increase in total miles. Best Line of Minneapolis, Minnesota, estimates a $10,000 per month savings since 300 drivers previously lost about 15 minutes each day waiting to talk with dispatchers.. Mets of Indianapolis, Indiana, performed tests that showed vehicle utilization increased by 13%.*** In addition, United Van Lines of Fenton, Missouri, claims that the ability to track and recover stolen vehicles is expected to reduce theft insurance premiums. (Information repeated in Section 2.1.4.1 and Section 2.6.3.1)

Additional results are provided in an ATA Foundation 1992 survey[77] of 69 trucking companies operating in an urban area. More than half of the 69 companies surveyed use CAD systems. ***Productivity gains resulted from an increase in the number of pickups and deliveries per truck per day, ranging from 5% to more than 25%, with most gains being clustered in the 10-20% range.*** The use of two-way text communication systems yielded driver time savings of 30 minutes per day because of the reduced time spent locating and using telephones.

#### 2.5.3.2 Anecdotal Cost Reduction Benefits of CVO

Further anecdotal evidence of benefits fleet management systems to carriers is accumulating. The recently completed Automated Mileage and Stateline Crossing Operational Test (AMASCOT) has generated significant interest from carriers, manufacturers, and regulators, with carriers awaiting delivery of orders for commercial products (Estel Cooper, Ruan Transportation, personal interview, April 1996). Although the evaluation did not calculate cost savings from the operational phase, carriers involved in the test estimated a potential for similar devices to reduce costs for International Fuel Tax Agreement (IFTA) and International Registration Plan (IRP) reporting by 33% to 50%. State processing and audit staffs were also receptive to potential changes in processing requirements and optimistic about the ability of such a system to improve accuracy, productivity, and compliance for both carriers and states[78].

Commercial Vehicle Regulators will also experience financial benefits due to implementation of ITS. Improvements in administrative efficiency, avoidance of infrastructure investment, and improvements in highway data collection will reduce costs while increased compliance will increase revenues and reduce damage to highways in addition to improving safety. The HELP/Crescent Project on the West Coast and Southern border states represented the final stage of the HELP program that evaluated the applicability of four technologies to services including roadside dimension and weight compliance screening, pre-screening of vehicles with proper documents, government audit of carrier records, government processing of commercial vehicle operator documents, government planning, and industry administration of vehicles and drivers. The technologies included automatic vehicle identification, weigh-in-motion, automatic vehicle

76 Hallowell, S., and Morlok, E., "Estimating Cost Savings From Advanced Vehicle Monitoring and Telecommunicating Systems in Intercity Irregular Route Trucking," Department of Systems, University of Pennsylvania, Philadelphia, PA, January 1992.

77 ATA Foundation, Inc., "A Survey of the Use of Six Computing and Communications Technologies in Urban Trucking Operations," Alexandria, VA, 1992.

78 Center for Transportation Research and Education, "Automated Mileage and Stateline Crossing Operational Test Evaluation Summary," Final Report, Federal Highway Administration, May 1996.

classification, and integrated communications systems and database. The benefits data are developed as a projection of experience from the project and from other databases rather than direct measurement by the project.[79] ***Impact of hazardous material incidents could be reduced $1.7 million annually per state. Estimates of reductions in tax evasion range from $0.5 to $1.8 million annually per state. Overweight loads could be reduced by 5% leading to a savings of $5.6 million annually. Operating costs of a weigh station could be reduced up to $160,000, with credentials checking adding $4.3 – $8.6 million and automated safety inspection adding $156,000 – $781,000 in savings due to avoided accidents annually per state.*** A full implementation of services examined in the Crescent project would yield a benefit/cost ratio of 4.8 for state government over a 20-year period. Less complete implementations range in benefit/cost ratio from 0 up to 12:l for the government. The COVE Study[80] estimates a benefit/cost ratio to the government of 7.2 for electronic clearance, 7.9 for one-stop/no-stop shopping, and 5.4 for automated roadside inspections. Another study finds that administrative compliance costs for Massachusetts carriers could be reduced by $2.4 million annually using ITS techniques[81].

#### *2.5.3.3* Predicted Cost Reduction Benefits of CVO

An extensive benefit/cost analysis of CVO user services effects on regulatory compliance cost of motor carriers predicted a range of benefits. The study segmented the motor carrier industry into small firms (1 - 10 power units), medium-sized firms (11 - 99 power units), and large firms (100 or more power units) and analyzed each user service from the perspective of each market segment. The predicted benefit cost ratios are generally larger for larger firms. The benefit/cost ratio for commercial vehicle administrative processes range from 19.8: 1 to 1.0: 1. For electronic screening the benefit/cost ratio ranges from 6.5: 1 to 1.9: 1. The benefit/cost ratio for automated roadside safety inspection ranged from 1.3: 1 to 1.4: 1. The benefit/cost ratio for on-board safety monitoring ranged from 0.49: 1 to 0.02: 1. For hazardous materials incident response, the benefit/cost ratio ranged from 2.5: 1 to 0.3: 1.[82] The narrow definition of benefits examined in this study indicate that these benefit estimates are conservative.

Electronic Information Exchange for fare payment and screening of commercial vehicles represent areas of high benefit potential. The Detroit, Michigan, to Windsor, Ontario, Canada, area experiences about 22 million border crossings annually, with roughly 75% of the crossings being made by daily crossers[83]. The NAFTA and development of local attractions such as the Windsor Casino are likely to cause significant increases in demand. Implementation of Automated Vehicle Identification (AVI) for use with Electronic Toll Collection and Customs and Immigration automation has the potential to benefit both the toll authorities and the Customs offices with payback on electronic equipment investment in less than five years for toll authorities and less than ten years for customs. ***If potential economic development is included, government payback is in one year. For auto users, delay costs would repay investment in about 2 years.*** Commercial vehicles would get a benefit/cost ratio of over 4: 1 in a single year, again

79 The Crescent Project: An Evaluation of an Element of the HELP Program, The Crescent Evaluation Team, Executive Summary and Appendix A, February 1994.

80 Study of Commercial Vehicle Operations and Institutional Barriers, Appendix F, Booz, Allen & Hamilton, McLean, VA, November 1994.

81 Kiley, K., Massachusetts Metro Transportation Association, Presentation at the ITS America Sixth Annual Meeting, April 1996.

82 "Assessment of Intelligent Transportation Systems/Commercial Vehicle Operations Users Services: ITS/CVO Qualitative Benefit/Cost Analysis - Executive Summary," American Trucking Associations Foundation, Inc., Alexandria, VA, 1996.

83 Study of Institutional Impacts of New Technology Applications: St. Clair and Detroit Rivers Highway Border Crossings, Marshall Macklin Monaghan Limited with KPMG, JHK, & Constance Consultants, May 1994.

primarily due to delay reductions. Additional benefits would accrue in ability to defer infrastructure investment, with benefit/cost ratio estimated at 30:1[84].

Motor carriers are currently involved with development of additional fleet equipage related to electronic tags, enhanced communications, and potential CVO architecture standards. ***A study of real-time diversion of truckload carriers predicted an additional productivity improvement of*** 6%.[85] Currently, the individual companies are equipping their own fleets with custom systems that provide them with competitive advantage, but may or may not fit with eventual standards.

### 2.5.4 Cost Reduction Benefits of Integrated Systems

Integrated systems have the potential to lower costs by sharing infrastructure, staff, and equipment costs among a number of services and organizations.

#### 2.5.4.1 Predicted Cost Reduction Benefits of Integrated Systems

Analysis performed for the USDOT ITS Joint Program Office indicated that ***incorporation of the full Intelligent Transportation Infrastructure into a regional transportation improvement plan could reduce the cost of infrastructure expansion by approximately half*** This analysis was based on published data regarding VMT growth, ITI component benefits, and FHWA cost estimates[86].

## 2.6 CUSTOMER SATISFACTION

Customer satisfaction indicates the degree to which transportation consumers are accommodated by ITS service offerings. Although satisfaction is difficult to measure directly, measures related to satisfaction can be observed including amount of travel in various modes, mode options, and the quality of service as well as the volume of complaints and/or compliments received by service providers.

### 2.6.1 Customer Satisfaction Benefits of ATIS

Traveler information systems can improve customer (i.e. traveler) satisfaction by reducing stress associated with navigation and travel time estimation. Road and transit network information reduce uncertainty in travel times, bus schedules and adherence status, travel options, and transportation network conditions. Information provided on alternate routes and modes gives the traveler additional travel options.

#### 2.6.1.1 Measured Customer Satisfaction Benefits of ATIS

One indication of reduced travel stress is the availability of information. ***Of rental users of TravTek, 38% found the device helpful in finding specific destinations in unfamiliar territory as did 63% of local drivers***[87]. In the Pathfinder project users perceived that their trips were less stressful and that they were saving time, even in situations where the time savings were insignificant. Drivers were also more comfortable in diverting with Pathfinder, as indicated by a

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84 Zavergiu, R., Unpublished Analysis Performed for Transport Canada

85 Regan, A., et al., Improving Efficiency of Commercial Vehicle Operations Using Real-Time Information: Potential Uses and Assignment Strategies, Presented at the 74th Transportation Research Board Annual Meeting, January 1995

86 Peters, J., and McGurrin, M., unpublished analysis.

87 Inman, V., et. al., "TravTek Evaluation: Rental and Local User Study," FHWA-RD-96-028, Federal Highway Administration, March 19%.

40% increase in diversion[88]. The Avis fleet of navigation equipped cars is expanding and frequently fully rented[89].

#### 2.6.1.2 Anecdotal Customer Satisfaction Benefits of ATIS

Pre-trip traveler information is also popular, although measures of reduced stress are difficult to obtain. The Los Angeles Smart Traveler project has deployed a small number of information kiosks in locations such as office lobbies and shopping plazas[90]. ***The number of daily accesses range from 20 to 100 in a 20-hour day,*** with the lowest volume in offices and the greatest in busy pedestrian areas. The most frequent request was for a freeway map with 83% of users requesting this information. Over half of the accesses included requests for MTA bus and train information. Users, primarily upper middle class in the test area, were overwhelmingly positive in response to a survey.

The Travlink test in the Minneapolis area distributed PC and videotext terminals to 315 users and made available transit route and schedule information, including schedule adherence information, as well as traffic incidents and construction information[91]. ***For the month of July 1995, users logged on to the system a total of 1660 times, an average of slightly more than one access per participant per week.*** One third of the accesses to the system requested bus schedule adherence; another 31% examined bus schedules. Additionally, three downtown kiosks offering similar information averaged a total of 71 accesses per weekday between January and July of 1995; real-time traffic data were more frequently requested than bus schedule adherence.

The Genesis project, also in Minneapolis, delivered incident information via alphanumeric pagers. A majority of Genesis users (65%) reported using the service daily and 88% reported using the service once or more per week. Of users who participated in the test, only 2% dropped out of the project during operation due to dissatisfaction with the service. An additional indication that users found the service valuable is that users discovered over half of the incidents affecting their travel via Genesis compared to discovering 15% of incidents via radio and TV. ***When users became aware of incidents via Genesis, they chose alternate routes for travel in 83% of the situations[92].***

***An automated transit information system implemented by the Rochester-Genesee Regional Transportation Authority resulted in an increase in calling volume of 80%[93], while a system installed by New Jersey Transit reduced caller wait time from an average of 85 seconds to 27 seconds and reduced caller hang-up rate from 10% to 3% while increasing the total number of caller.[94] The Boston SmarTraveler has experienced 138% increase in usage from October 1994 to October I995 to a total of 244,182 calls monthly, partly due to a partnership with a local cellular telephone service provider, according to a SmartRoute Systems memorandum entitled SmarTraveler Update dated November 6, 1995.***

TravTek users perceived that their driving was safer. Based on survey data, users felt less nervous and confused and more confident, attentive, and safe, with local users being significantly

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88 Pathfmder Evaluation Report, Prepared for California Department of Transportation, JHK & Associates, Pasadena, CA, February 1993.

89 "Avis Finds In-Vehicle Navigation a Success," Urban Transportation Monitor, Oct. 27, 1995.

90 Giuliano, G., et al., "Los Angeles Smart Traveler Information Kiosks: A Preliminary Report," Presented at the 74th Transportation Research Board Annual Meeting, January 1995.

91 Remer, M., Atherton, T., and Gardner, W., ITS Benefits, Evaluation and Costs: Results and Lessons from the Minnesota Guidestar Travlink Operational Test, Draft, November 1995.

92 Wetherby, B., facsimile transmission of data presented to Genesis working group, March 1996.

93 USDOT, Federal Transit Administration, APTS Benefits, November 1995.

94 "NJ Transit's Customer Information Speeded Up by New System," Passenger Transport, January 24, 1994.

more positive than renters. Users also felt that the use of TravTek did not interfere with their driving task. While users who were interacting with TravTek immediately before a near accident were more likely to feel that they had contributed to the close call, users were no more likely to be involved in close calls than were nonuser[95].

### 2.6.2 Customer Satisfaction Benefits of ATMS

Traffic management systems are able to reduce stress associated with travel by smoothing the flow of traffic and reducing the variability of travel times.

#### 2.6.2.1 Measured Customer Satisfaction Benefits of ATMS

Traffic signal system improvements are able to reduce the number of vehicle stops. ***Quoting studies mentioned earlier, ATSAC reported 41% reduction in vehicle stops[96]. SCOOT in Toronto resulted in a 22% decrease in stops[97] compared to a "best effort" fixed timing plan.*** The Abilene report indicates no change in the number of stops[98].

### 2.6.3 Customer Satisfaction Benefits of APTS

Advanced public transportation systems reduce stress by improving the security of the patron, providing information about the trip, increasing the convenience of purchasing passage, and reducing variation from schedule.

#### 2.6.3.1 Anecdotal Customer Satisfaction Benefits of APTS

For the transit riding public, security is a crucial issue. Everyday there are numerous emergency situations in every major city involving passenger and operator safety. The deployment of automatic vehicle location (AVL) systems coupled with modern computer-aided dispatch (CAD) as part of transit management systems has had a dramatic affect on the response to emergencies. The AVL/CAD systems now being deployed have two key features which contribute to passenger safety. First, these systems have a silent alarm capability where the driver can alert the dispatch center of a problem. When this alarm is activated, the vehicle in trouble is highlighted on the dispatcher's console for immediate response. The dispatcher can activate a covert microphone on the bus and listen to the nature of the problem without alerting the perpetrators or passengers. The dispatcher can then alert the appropriate emergency service. A number of transit agencies have reported a dramatic reduction in response time. ***The fact that the dispatcher can pinpoint the vehicle at all times, and is able to advise the police of the nature of the problem has produced a reduction in response time from over ten minutes to less than two minutes[99].*** At least one dispatcher in Denver believes that this capability has literally saved the lives of some passengers.

Electronic fare payment tests are ongoing in both bus and rail systems which address customer convenience and security. In California, tests comparing various card technologies have found

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95 Inman, V., et. al., "TravTek Evaluation: Rental and Local User Study," FHWA-RD-96-028, Federal Highway Administration, March 1994.

96 City of Los Angeles Department of Transportation, "Automated Traffic Surveillance and Control (ATSAC) Evaluation Study," June 1994.

97 Siemens Automotive, USA, "SCOOT in Toronto," Traffic Technology International, Spring 1995.

98 Orcutt Associates, "Evaluation Study, Buffalo Gap Road, Abilene Signal System," prepared for the City of Abilene, Texas, 1994

99 Jones, W., ITS Technologies in Public Transit: Deployment and Benefits, USDOT ITS Joint Program Office, November 1995.

RF proximity cards to be high in reliability. A test in the Marseilles, France, metropolitan area is comparing RF and IR technologies that would allow each patron to use a card of his or her choice (credit card, debit card, monthly pass, etc.) for transportation payment, while processing a transaction in less than a second[100]. An experiment involving 2400 rail travelers in the Washington system using RF stored-value cards has been operating since February of 1995. ***System-wide deployment of the cards is planned based on the reliability of the technology and potential improvements in convenience and security*** (Ramon Abramovitch, Washington METRO, telephone interview, November 1995).

The Phoenix transit operators have used electronic fare payment techniques since 1991[101] The Arizona state legislature passed an air quality bill in the late 1980s. Maricopa County, the county encompassing Phoenix, in turn passed a travel reduction ordinance that required each employer in the Phoenix area with over 100 employees to reduce single-occupancy commuting trips by 5% in two years. To assist in data collection needed in this program as well as to reduce operational problems, the City of Phoenix Public Transport System led development of the Bus Card Plus system to read magnetically encoded plastic passes. Employers were then billed monthly for transit use by their employees.

The first public use of the Phoenix system was in April 1991 by employees of Valley National Bank. Currently, 190 companies participate with a total of 35,000 cards in use. ***Express routes report 90% of fares are paid by bus pass cards.*** Since employers are billed only for transit usage rather than purchasing monthly passes, costs to them are decreasing by up to one third. Starting in May of 1995, VISA and MasterCard have also been accepted. While this project has not been in operation long enough for firm results to be claimed, patronage has been growing over the four months from May - September, with processing fees totaling under 7% of revenue generated and without major problems.

### 2.6.4 Customer Satisfaction Benefits of CVO

Customer satisfaction improvements to regulators relate to improved service to commercial vehicle operators in the form of reduced time for inspections and credentials acquisition and improved service to the traveling public in the form of more effective apprehension of unsafe commercial vehicles. Customer satisfaction improvements to the commercial vehicle operators relate to reduced travel time and variability in travel time and increased flexibility in scheduling service.

#### 2.6.4.1 Measured Customer Satisfaction Benefits of CVO

The Commercial Vehicle Operations (CVO) area continues to be viewed as a potential early winner for the ITS program. Use of advanced vehicle monitoring and communications technologies by motor carriers has demonstrated considerable improvements in customer service and driver retention[102]. ***Schneider of Green Bay, Wisconsin, reports a 20% increase in loaded miles and that the elimination of driver check-in telephone calls saves approximately two hours per day resulting in a driver salary increase of $50 per week with a primary benefit of improved customer service. Trans-Western Ltd. of Lerner, Colorado, credits their fleet management system for improved driver relations, noting that drivers are able to drive 50 to 100 additional***

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100 Mathieu, J., "Multiservices/Multproviders Remote Ticketing on the Marseille Metropolitan Area," Proceedings of the Second World Congress on Intelligent Transport Systems, November 1995.

101 Schwenk, J., "Bus Fare Payment with Credit Cards in Phoenix," draft, The Volpe Center, November 1995.

102 Hallowell, S., and Morlok, E., "Estimating Cost Savings From Advanced Vehicle Monitoring and Telecommunicating Systems in Intercity Irregular Route Trucking," Department of Systems, University of Pennsylvania, Philadelphia, PA, January 1992.

***miles per day and driver turn-over has decreased from 100% to 30%. North American Van Lines of Fort Wayne, Indiana reports 16.9% additional shipments, 5.7% fewer deadhead miles, and 3.8% fewer cancellations.*** (Information repeated in Section 2.1.4.1 and Section 2.5.3.1)

#### 2.6.4.2 Predicted Customer Satisfaction Benefits of CVO

Although Commercial Vehicle drivers differ significantly in their views about CVO services, a large majority view the implementation of some or all of the services favorably. In a 1995 survey of 1582 commercial vehicle drivers, 46% of the drivers viewed all applicable CVO services favorably, while 12% viewed none of the services favorably. The remaining 42% viewed some, but not all of the services favorably. The ratio of truck drivers viewing services strongly favorable to those who completely opposed them ranged from 7.9: 1 for hazardous materials incident response to 0.7: 1 for on-board safety monitoring. For motorcoach operators, the ratio ranged from 6.1: 1 for commercial fleet management to 2: 1 for on-board safety monitoring[103].

## 2.7 OTHER BENEFITS

### 2.7.1 Energy and Environment

Environmental benefits from a given project can only be estimated by analysis and simulation in most situations. The problems related to regional measurement include small impact of individual measures and large numbers of exogenous variables including weather, contributions from non-mobile sources or other regions, and the time evolving nature of ozone pollution.

One case where direct measurement of environmental impact is practical is a highly localized measure such as air quality surrounding a particularly snarled intersection or other point of interest. An example of local air quality benefit is the reduction of emissions using signal system optimization in the "Five Points" area of Las Vegas[104].

Traveler information can have a positive effect on emissions. Surveys performed in the Seattle, Washington area and the Boston, Massachusetts area indicate that when provided with better traveler information, there is a nearly even split between travelers who change route of travel and travelers who change time of travel, with an additional 5%-10%[105] changing travel mode based on traveler information. Assuming that 30% of the 96,000 daily callers projected for 1999 change travel plans according to this breakdown, the impact of SmarTraveler in Boston on emissions has been estimated using the MOBILE5a model. ***On a daily basis, this adjustment of travel behavior nets an estimated reduction of 498 kg of volatile organic compounds, 25 kg of NOx, and 5032 kg of CO representing reductions of 25%, 1.5%, and 33% respectively of these pollutants from travelers changing travel plans.*** While this represents significant reductions for participating travelers, only 28,800 daily trips are expected to be affected in a metropolitan area with 2.9 million registered drivers. Simulations based on TravTek experience yield similar, but less optimistic, results.

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103 Penn + Shoen Associates, "Driver Acceptance of Commercial Vehicle Operations (CVO) Technology in the Motor Carrier Environmenr Executive Summary," Federal Highway Administration, DTFH61-94-C-00182, undated.

104 Reduction in Localized Carbon Monoxide Emissions, Draft, Submitted to the Clark County Health District by Barton-Aschman Associates, Inc., November 1994.

105 Tech Environmental, Inc., "Air Quality Benefit Study of the SmarTraveler Advanced Traveler Information Service," July 1993

The Pike Pass ETC program on the Oklahoma Turnpike started operation on 1 January 1991. As of June 1994, 250,000 passes had been issued, of which over 90% (226,000) were still active, accounting for 35% of the turnpike association's revenue. Using a protocol prepared from the Northeast States for Coordinated Air Use Management (NESCAUM), the Clean Air Action Corp.[106] estimated toll booth emissions based on dynamometer tests and toll road observation at Muskogee Turnpike in Oklahoma, Asbury Plaza on the Garden State Parkway in New Jersey, and Western Plaza on the Massachusetts Turnpike. This report takes the experiences gained with the Pike Pass project and applies them to the other two freeways. The report projects significant reduction in tons of pollutants for the 260 day commuter case. The overall percent change is dependent upon frequency of toll plazas. ***Per mile of impacted operation, the average emissions reductions are 72% for carbon monoxide, 83% for hydrocarbons, and 45% for oxides of nitrogen.*** The report uses 0.55 miles as the distance involved in the average barrier toll transaction.

Traffic signal systems continue to be upgraded for a number of reasons, primarily for traffic flow and system maintenance reasons. The improved flow and reduced delays also have a generally positive impact on emissions and energy consumption at current traffic levels. Several system retimings and equipment upgrades have included emission evaluations. Among documented results are systems in Abilene, Texas, Southern California, and Toronto, Ontario. The ATSAC program in Los Angeles, California ***reported 13% decrease in fuel consumption, 14% decrease in emissions[107].*** The City of Abilene report[108] ***indicates overall impacts on emissions of 6% decrease in fuel consumption, 10% decrease in HC, and 13% decrease in CO, while nitrous oxide increased by 4%. The SCOOT implementation in Toronto showed a decrease in fuel consumption of 6%, a decrease in carbon monoxide emission of 5%, and a decrease in hydrocarbon emissions of*** 4% compared to a "best effort" fixed timing plan[109].

Several studies, including one from Illinois Department of Transportation (DOT)[110] and another from the National Research Council[111] report that 60% of the mobile source pollution arise from "gross polluters" comprising only 10% of the vehicles. The Arizona-Department of Environmental Protection has implemented a program in the Phoenix area, which is a non attainment area for ozone, to use a remote sensing device to identify gross polluters (Frank Cox, Arizona Department of Environment, telephone interview, April 1995). Two operational tests are under development that test concepts to identify these vehicles and bring down their pollution levels. The voluntary emissions compliance test near Denver is in the calibration stage. The remote emissions monitoring technology has been used previously, but the overall impact of such a device is not yet known.

As a result of reduction in delay and travel time, emissions will also be reduced. According to analysis in considering expansion of the Detroit freeway management center,[112] ***delay under***

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106 Clean Air Action Corp., "Proposed General Protocol for Determination of Emission Reduction Credits Created by Implementing an Electronic Pie Pass System on a Tollway," Study for the Northeast States for Coordinated Air Use Management, December, 1993.

107 City of Los Angeles Department of Transportation, "Automated Traffic Surveillance and Control (ATSAC) Evaluation Study," June 1994.

108 Orcutt Associates, "Evaluation Study, Buffalo Gap Road, Abilene Signal System," prepared for the City of Abilene, Texas, 1994

109 Siemens Automotive, USA, "SCOOT in Toronto," Traffic Technology International, Spring 1995.

110 Environmental Planning and Economics, Inc., "Cleaning the Air, Choosing the Future: Reducing Highway Vehicle Emissions in the Chicago Non-Attainment Area," submitted to the Illinois Department of Environment and Natural Resources, Springfield, Illinois, 1992.

111 National Research Council, "Rethinking the Ozone Problem in Urban and Regional Air Pollution," National Academy Press, 1991.

112 Early Deployment of ATMS/ATIS for Metropolitan Detroit, prepared for Michigan DOT by Rockwell

***incident conditions would be reduced by about 40%, resulting annually in a reduction of 41.3 million gallons of fuel used (42%) and reducing carbon monoxide emissions by 122,000 tons, hydrocarbon emissions by 1400 tons, and oxides of nitrogen emissions by 1200 tons***. These estimates assume that the freeway management system would not change vehicle miles traveled.

International, Dunn Engineering, and Hubbel, Roth & Clark, February 1994.

# SECTION 3

## SUMMARY

The evidence of potential benefits from ITS deployment is becoming compelling. To date, however, only a small subset of outcomes have been demonstrated and measured in the field. In the safety arena, for example, the ability of only a small subset of ITS to reduce the number of crashes has been measured in the field. With the generally high level of safety present in today's highway environment, statistically significant outcome measures will accumulate slowly. Statistically significant results in fatality reductions will be even slower in developing.

This paper has highlighted some field experience in meeting goals and has presented additional evidence that ITS implementations are capable of meeting those goals. It has demonstrated the complementary nature of measurement, anecdote, and simulation analysis. By relating results data to key measures developed by the USDOT, the paper identifies places where important benefits data are missing. It is hoped that the document can serve to focus efforts to fill gaps in knowledge of such benefits as fatality reduction, throughput increase, customer service improvement, and fuel savings and emissions reductions. In addition, further work is needed to characterize the relationship of benefits to costs of various systems and to enable better estimates of the benefits from a particular planned deployment.

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